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AND ABSTRACT OF THE LITERATURE

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Acute Respiratory Infections among Motormen and Conductors

The Cardiac Patient in Industry: Chicago Heart Association Plans Constructive Program. Data from Thirty-Four Industries

Metal Fume Fever: III. The Effects of Inhaling Magnesium Oxide Fume

Basophilic Material in Benzol Poisoning: A Preliminary Report

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ACUTE RESPIRATORY INFECTIONS AMONG MOTORMEN AND CONDUCTORS*

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PHYSICIANS who are concerned with the morbidity among large groups of individuals, whether these be in schools, in army camps, or in industries, realize that there is no health problem which compares in importance to the so-called "acute cold." Most persons, when they contract colds, lose little or no time from their duties, but the number of persons affected each year is so large that the aggregate time lost from colds far surpasses that from any other disease; consequently more and more attention is being given to the etiology, the epidemiology, the predisposing factors, and the prevention of colds. It was with the hope of obtaining some additional data on the epidemiology of colds that the study reported in this paper was undertaken.

The Minneapolis Street Railway Company maintains a medical service for its employees and keeps accurate records of their illnesses. The Medical Director of the Company, who is one of the authors, made these records available for study, and for a period of six years, 1918 to 1923, inclusive, the time lost on account of acute respiratory infections was tabulated separately for motormen and for conductors. In the cars used on these lines the motormen are enclosed in booths in the front of the cars, while the conductors stand just in-

* Received for publication Jan. 25, 1927.

side the rear doors, at stations in the midst of the stream of passengers, to collect fares as the passengers enter or leave the cars. These conditions under which motormen and conductors work, particularly with regard to exposure to the public, seemed sufficiently different to justify a comparison of the infections in the two groups.

Individuals Losing Time from Colds

The number of motormen and the number of conductors who lost at least one day on account of colds during each of the years from 1918 to 1923 are shown in Table 1. The term "colds" as used in this study included diagnoses of rhinitis, pharyngitis, laryngitis, bronchitis, grip, and "cold." The percentages of motormen and of conductors affected, as given in the table, are not absolutely accurate,[1] because the only figures available concerning the number of employees included both the motormen and the conductors. However, since motormen and conductors work in pairs, the number of each employed from day to day is about equal; therefore, in computing the percentages in Table 1 the number of motormen and the number of conductors were each taken as one-half of the mean total for the year.

This table shows that each year, with the exception of the year 1919, a larger proportion of conductors than of motormen lost time from colds. A more detailed analysis reveals the fact that during the last few months of 1918 as well as during 1919—influenza years—the percentage of

TABLE 1.—NUMBER OF INDIVIDUALS WHO LOST TIME ON ACCOUNT OF COLDS

YEAR	TOTAL EMPLOYED	NUMBER WHO LOST TIME		PERCENTAGE WHO LOST TIME	
		Motormen	Conductors	Motormen	Conductors
1918	2,050	140	170	13.7	16.6
1919	2,366	112	112	9.5	9.5
1920	2,432	155	173	12.7	14.2
1921	2,336	89	178	7.6	15.2
1922	2,356	119	179	10.1	15.2
1923	2,266	61	92	5.4	8.1
Average.....	2,301	112.7	150.7	9.8	13.1

motormen equaled the percentage of conductors losing time. Averaged for the six years, 9.8 per cent. of the motormen and 13.1 per cent. of the conductors lost more than one day each year from colds. The percentages of those who lost time varied widely from year to year, both for motormen and for conductors, the peaks for both being in 1918 and the low points in 1923.

Time Lost from Colds

The days that all employees lost were totaled for each year and the summary is shown in Table 2. The average number of days lost per illness was computed by dividing the total days lost by the number who were ill.

The average time, 3.5 days, lost per

[1] Case records do not show absences of less than one day.

cold, would seem to indicate that with the mild infections the men continued on duty and that when they did give up they were usually rather severely ill. The total time lost by conductors per year was 42 per cent. more than the time lost by motormen, but the average time lost per illness by the two groups was almost the same. In both groups the time lost per illness was greater during 1918, 1919, and 1920 than during the last three years of the study.

TABLE 2.—NUMBER OF DAYS LOST FROM COLDS

YEAR	TOTAL NUMBER OF DAYS LOST		AVERAGE NUMBER OF DAYS LOST PER PERSON ILL	
	Motormen	Conductors	Motormen	Conductors
1918	681	818	4.9	4.9
1919	441	624	3.7	5.7
1920	548	661	3.5	3.8
1921	195	411	2.2	2.3
1922	312	526	2.6	2.9
1923	123	220	2.0	2.4
Average....	383.3	543.3	3.2	3.7

The economic yearly loss from these colds, calculated on an average wage of $4.50 per day, was slightly over $4,000.

Incidence of Other Acute Contagious Diseases

Although the acute contagious diseases are not common in age groups represented by street car employees, they occur occasionally; and, as with acute colds, conductors would have much more exposure than motormen to mild atypical cases, carriers, and others in the traveling public. Table 3 shows the number of persons infected and the time lost by motormen and by conductors from scarlet fever, diphtheria, measles, mumps, and smallpox, during the five years 1918 to 1922.

During this period two motormen and four conductors contracted scarlet fever, but more motormen than conductors were ill from diphtheria, measles, mumps, and smallpox. During the same time four conductors had lobar pneumonia while none of the motormen contracted this disease.

Intensive Study of an Epidemic of Influenza

During the months of March and April, 1925, throughout this section of the country many persons were ill with a disease presenting the symptom-complex commonly called mild influenza. The incidence of this infection was studied among the motormen and the conductors from four of the barns or stations of the Minneapolis Street Railway Company. Figure 1 displays the courses of these infections among the men from the various stations. The cars which went out from all these stations ran through the down town "loop" district.

Among the men from station 1, the infections were rather evenly divided among the motormen and the conductors, although the motormen lost somewhat more time than did the conductors. The infections also were almost equally divided among the men from station 2 until the 25th of March, after which date the number

of motormen ill was continuously higher than the number of conductors.

TABLE 3.—NUMBER OF DAYS LOST FROM ACUTE CONTAGIOUS DISEASES

YEAR	SCARLET FEVER				DIPHTHERIA				MEASLES				MUMPS				SMALLPOX			
	Cases		Days Lost		Cases		Days Lost		Cases		Days Lost		Cases		Days Lost		Cases		Days Lost	
	Motormen	Conductors	Motormen	Conductors	Motormen	Conductors	Motormen	Conductors	Motormen	Conductors	Motormen	Conductors	Motormen	Conductors	Motormen	Conductors	Motormen	Conductors	Motormen	Conductors
1918	1	2	35	35	...	1	...	28	3	3	55	58	...	2	...	12	1	...	35	...
1919	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	4	...	...	...	...
1920	...	1	...	8	1	1	56	26	1	...	11	...	4	1	45	9	1	1	24	39
1921	1	1	28	60	2	...	19	...	...	...	...	...	7	1	89	5	2	1	47	21
1922	...	...	...	...	1	...	18	...	...	...	...	...	2	...	26	...	...	...	...	...
Total.....	2	4	63	103	4	2	93	54	4	3	66	58	13	5	160	30	4	2	106	60

From station 3 the motormen and conductors were about equally affected throughout the entire period. But from station 4 more conductors than motormen were ill each day of the epidemic.

Comment

There are today three factors which are rather generally accepted as etiologic in the production of colds. These are: (1) nonspecific, nonbacterial factors, such as physical and chemical irritants, exposure to cold, and various reflex conditions; (2) a local or general hypersensitive condition to such substances as plant pollens, animal emanations, and certain foods; and (3) infecting micro-organisms with virulence sufficiently high to set up an infection upon the nasal mucous membranes of most persons. This last constitutes the true infectious cold and is the one which would seem most likely to account for any differences in the incidence of colds between motormen and conductors. In a large group of employees there is no reason to think that in one half there should be more persons hypersensitive than in the other half. The exposure to colds and drafts might vary between motormen and conductors, but both groups are greatly exposed to outdoor conditions and so should be hardened to withstand them. The relationship which has been pointed out between the incidence of colds, the mean outdoor temperature, and the average daily sunshine[2] could hardly account for the difference noted between these two groups. In the amount of exposure to the general public, however, there is distinct difference between motormen and conductors, the conductors being continuously exposed

[2] Smiley, D. F.: Seasonal Factors in the Incidence of the Acute Respiratory Infections. Am. Jour. Hyg., 1926, *6*, 621.

directly to spray borne infection and indirectly through hands, money, etc.; conductors to conductors during their hours off duty must be responsible for

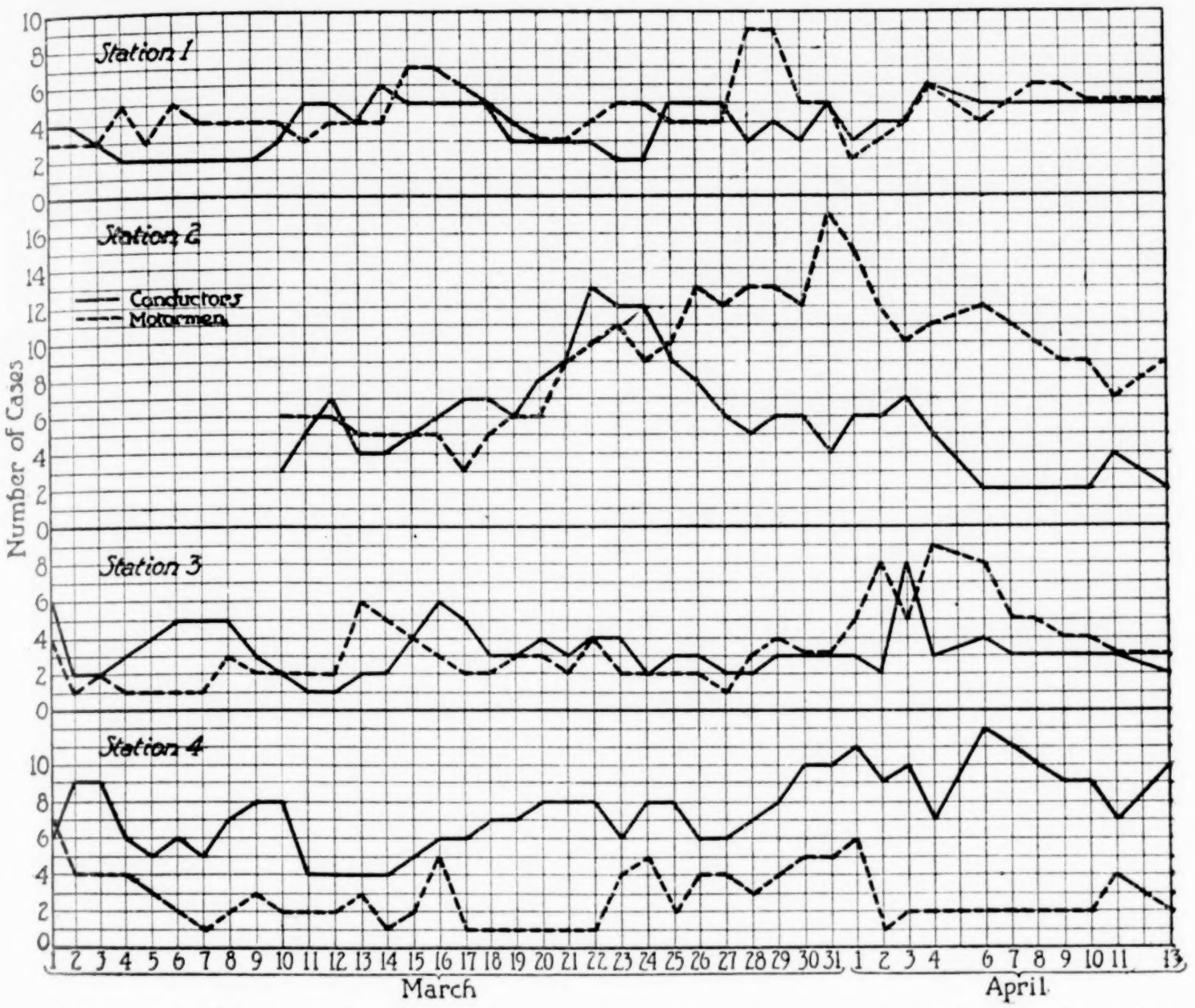

FIG. 1.—Incidence of mild influenza among motormen and conductors from four stations of the Minneapolis Street Railway Company during March and April, 1925.

while the motormen have practically no exposure to the public when on duty. Of course, for approximately two-thirds of the day, these men are off duty and could be exposed to infections by their fellow workmen, by the general public, and by their families. Such exposures probably account for the more specific infections, such as influenza, scarlet fever, diphtheria, and mumps, which attack motormen equally as frequently as they do conductors. It would seem also that the transmission of infection from motormen to motormen and from the predominance of infections among one group or the other as observed in the greater amount of influenza among the motormen from station 2, in the predominance of this same disease among conductors from station 4, and in the noticeable prevalence of mumps among motormen during the years 1920 and 1921.

Tables 1 and 2 show a decidedly greater incidence of colds and a greater loss of time from them among conductors than among motormen but one wonders whether there might not be some difference in the type of the

average individual in the two groups which might account, at least in part, for the difference in time lost. With this in mind the following hypothetical questions were submitted to the superintendent of employment and to four station foremen of the Street Railway Company:

1. Are there any differences between the type of men employed as motormen and the type employed as conductors?

2. If 100 motormen and 100 conductors were equally sick, which group would lay off most? In what proportion?

Their judgment regarding the type of men employed for the two classes of work is that "the motormen are more rugged, stolid and older; while the conductors are of a more asthenic type, more intelligent and younger." The replies to the questions regarding the proportion of motormen as compared to conductors who would lose time from the same degree of illness gave the ratios of motormen to conductors as: 4:5, 3.5:6.5, 2:3, 3:5, and 5:5—an average of 3.5:4.8.

Hence, according to the opinion of these foremen the differences in the type of individuals would account for 37 per cent. greater loss of time by conductors than by motormen. If these opinions are correct, the difference in exposure to infections would not need to account for any of the difference in the number of conductors and the number of motormen who were off duty, the average for conductors being only 34 per cent. greater than the average for motormen. This would seem to add further evidence to the conclusion of Winholt and Jordan[3] that the transmission of colds by contact usually requires rather close exposure.

Summary

1. A study covering a six-year period was made of the incidence of acute respiratory infections among motormen and conductors employed by a large street railway company.

2. During this period the conductors lost more time from the so-called "acute cold" than did the motormen.

3. The greater loss of time by conductors was due chiefly to a large number of conductors having colds; although they also showed more repeated infections and a slightly greater average loss of time from each infection.

4. Of the many factors which have been suggested as contributory in the development of colds, the greater exposure to the public seems to be the only one in which there would be a marked difference between a group of motormen and a group of conductors.

5. The opinions of five foremen of the street railway company would seem to indicate that the differences in the type of individuals employed as motormen and as conductors might be sufficient to account for the entire difference in time lost by the two groups.

6. The acute contagious diseases attacked more motormen than conductors during this period, which would seem to indicate that most of these in-

[3] Winholt, W. F., and Jordan, E. O.: Epidemiology of Colds in Infants. Jour. Am. Med. Assn., 1923, *81*, 280.

fections were contracted when the men were off duty.

7. An intensive study of an epidemic of mild influenza among the men from four stations showed that at two stations the motormen and conductors were about equally affected; that at one station more motormen were ill than conductors; and that at the fourth station more conductors than motormen were off duty. This would suggest that much of this infection was transmitted from motormen to motormen and from conductors to conductors when they were not on duty.

8. The financial loss due to acute respiratory infections which were incapacitating for at least one day averaged slightly over $4,000 per year.

THE CARDIAC PATIENT IN INDUSTRY: CHICAGO HEART ASSOCIATION PLANS CONSTRUCTIVE PROGRAM

DATA FROM THIRTY-FOUR INDUSTRIES*

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SERIOUS proposals are being made in Australia to establish a national institute wherein heart cripples who are unacceptable for public services and unable, because of workmen's compensation provisions, to be absorbed in industry may earn their basic wage. In this way it is hoped to avoid unemployment conditions and economic waste. The organization of industry in accordance with economic requirements is wasteful of all handicapped workers. Inflexibility of adjustments may even produce a public health menace. Employers, impeded by multiple regulations which they find difficult to apply, are slow to displace internal management schemes in the interest of individual workers or even to utilize a typical group of physical defectives.

Association Sponsors Certified Workers

The Chicago Heart Association, having conducted a study project within Chicago industries during the past year, now proposes a workshop laboratory under scientific supervision which will cover a job induction period for cardiac defectives who are to be certified by the Association for certain positions which they are found competent to fill. This corresponds to the Australian proposals except that here the industrial workshop will be utilized as a clearing house and not as a haven for handicapped workers. A refinement of ordinary personnel methods will replace haphazard employment within this group. A trained social worker to follow up certified workers and give a stability to case work heretofore unknown will gradually develop in the employer a confidence he does not now feel in this work. It is expected that this definition of activities will increase the prestige of the Heart Association work, for the workshop laboratory which is an integral part of the scheme will pursue fatigue studies of scientific value designed to develop a series of work tolerance tests for general use.

The four summarization tables presented with this article cover prelimi-

* Received for publication Dec. 22, 1926.

nary studies in the development of present placement plans carried on by Mrs. Gertrude Howe Britton, executive director of the Chicago Heart Association, with full assistance throughout the medical aspects of the situation by Dr. Wilma Cohn Sacks. Consultation was secured with individual members of the Chicago Society of Industrial Physicians on the direction which the study should take, and the information presented represents the direct aid given by employers, personnel men, and the medical staffs of the thirty-seven Chicago industries which maintain adequate or nearly adequate medical services for their employees. Comparable data from thirty-four industries covering physical examination records of nearly 400,000 men have been utilized in this study. Co-operation with existing agencies has been secured at every possible point and the workshop laboratory, which is an integral part of present plans, will be conducted in the industrial workshops of the Jewish Social Service Bureau. The placement expert will be jointly financed by the Heart Association and the Jewish Social Service Bureau in order to avoid ambiguities growing out of duplicated effort. Hereafter a IIA or a IIB classification of a cardiac defective will mean a definite set of physical factors well understood by all who are concerned in his placement, and it is expected that sentiment will not outrun sound judgment in placement work.

No high statistical value attaches to the percentages for cardiac defectives here given, for it is impossible to accept as final the recorded 1.34 per cent. of applicants for work who are rejected because of heart disease (see Table 1), in the face of the fortuitous manner in which examinations are made and of the incompleteness of records, particularly as concerns candidates for work. Rejection records were kept in only thirteen of the industries surveyed and they probably represent far less than the actual picture. In many concerns the physical examination is delayed for some weeks after employment. The rate of rejection ranging from 0.5 per cent. in one instance to 10 per cent. in another represents irreconcilable extremes. Diagnosis cannot be verified. Inadequate forms and the absence of specific tests undoubtedly allow the admission of many cases of undiscovered

TABLE 1.—DATA FROM THIRTEEN CHICAGO INDUSTRIES SHOWING 1.34 PER CENT. OF ALL EXAMINED APPLICANTS FOR WORK REJECTED BECAUSE OF HEART DEFECTS

FIRM NUMBER	NUMBER OF APPLICANTS		PERCENTAGE REJECTED
	Examined	Rejected	
2	1,750	159	9.0
4	600	3	0.5
8	7,000	70	1.0
10	1,000	20	2.0
11	1,615	52	3.2
16	200	5	2.5
18	1,697	46	2.7
19	23,618	550	2.3
20	160[1]	16	10.0
25	42,000	111	0.3
27	1,500	60	4.0
29	3,359[2]	187	5.5
31	14,575	48	0.3
Totals....	99,074	1,327	1.34

[1] Selected.
[2] Insured.

heart disease. Figures are equally vague regarding the incidence of heart disease among old employees, but it appears to be more than the generally accepted figure of 2 per cent.

The general attitude of the employer and the personnel group is unfavorable toward the cardiac worker "on the basis of experience," according to many of the reports. Very few, however, can state what that experience has been. Wherever there has been any proper analysis of the situation, the generally unfavorable impressions tend to disappear. One large industry which is without prejudice against employing selected cases reports good industrial output and an unusually low lost time record among workers of this class. It is the opinion of this industry that the handicapped worker appreciates his privilege to work, and that for the most part the physical condition improves under a regulated regimen. It is to be remembered in this connection that the insurance report of the committee on heart disease of the British Medical Research Committee found that all cases deteriorated under inactivity and that more than half of large groups of men improved progressively under graded work. The experience of this single firm with large groups of workers over a period of nine years confirms this observation. Old employees have their work adjusted but, unless change seems imperative, a shift of jobs is not made. The management chooses to avoid the psychic upset of ill-considered shifts and regards retraining as usually impracticable within the industry. A pension system provides for the case which becomes decompensated on the job. (It is to be noted also that the existence of pension systems seems to simplify internal difficulties of administration in the interest of the handicapped worker.)

The findings of this survey indicate that 1.34 per cent. of 99,074 applicants for work were rejected on account of heart disease and that some degree of heart disability affects 2.5 per cent. of the 395,084 workers within industry. It is evident that present policies of evasion on the part of industrial management have not been conspicuously successful in meeting the situation.

A still more acute condition affects the group of decompensating or relapsing heart conditions that are present in workers attendant upon the heart clinic. The 652 patients covered by the reports of these clinics (Table 2) represent a fairly high quota of frank decompensation cases. Of this group less than one-third are able to carry on their regular pursuits; 275 (42.3 per cent.) require shortened hours or modified activities; and 165 (25.3 per cent.) are incapable of regular work.

Cardiac workers have a very poor opportunity for employment in Chicago. Of thirty-four industries tabulated, only twenty-seven have a well-defined policy in connection with their employment. Nearly half of these reject all; eight will hire the well-compensated case, and two others make exceptions for highly skilled workers in positions which are hard to fill. It is noteworthy that the examining physician decides on the employability in only two industries. The decisions of personnel men rather than medical judgments account for some of the anomalies of the present situation.

Illinois workmen's compensation laws ignore heart disease. Industrial industry to constructive activity in this direction.

TABLE 2.—DATA FROM SIX CARDIAC CLINICS OVER A PERIOD OF ONE MONTH, SHOWING PLACEMENT NEEDS INDICATED BY WORKING CAPACITIES OF PATIENTS, AGE GROUPS FROM 20 TO 55 YEARS

CLINIC NUMBER	TOTAL CASES	CAPABLE OF REGULAR WORK			ADJUSTED TIME OR MODIFIED ACTIVITY NEEDED			NOT PLACEABLE	
		Male	Female	Per Cent.	Male	Female	Per Cent.	Number	Per Cent.
1	116	33	30	54.3	3	13	13.8	37	31.9
2	131	30	18	36.6	16	22	29.0	45	34.4
3	135	30	18	35.6	11	66	57.0	10	7.4
4	81	4	....	5.0	73	....	90.0	4	5.0
5	39	5	6	28.2	9	9	46.1	10	25.7
6	150	38	....	25.3	53	....	35.3	59	39.4
Totals....	652	140	72	32.5	165	110	42.2	165	25.3

diseases to be compensable must be shown to have arisen because of and in the course of work, and the occupational disease becomes an accident under the law. Heart disease is not in this sense occupational. Very few awards under workmen's compensation in Illinois have regarded the disabled heart as a possible contributing cause of accident. The contention has been made in fewer than half a dozen cases before the Illinois Industrial Commission. The decisions, however, do place responsibility for preexistent disease upon the employer and place upon him the burden of proof in such a case. Thus industry is perhaps justified in its present attitude of rejection. Any extensive program depends upon breaking down this resistance by means of more scientific approach to the whole problem. The amateur has no place in vocational adjustments. One heart defective badly placed can discredit an entire program and can close a whole

Health Depends on Work Adjustment

The Chicago Heart Association, organized in 1923, first turned its attention toward securing the essential special medical staff. Then affiliations with health and social agencies were effected, and a monthly bulletin informational in character was published to reach and cement the interests of widely divergent groups. Social investigations are made and suitable workers recommended to school clinics and to hospital and industrial dispensaries. The workshop laboratory and field supervision under a vocational expert complete the social machinery for a well-rounded program. Table 3 shows the relatively difficult problems of placement within the industries themselves and Table 4 gives a highly condensed statement of an analysis made of 155 jobs in various processes in fourteen industries wherein suitable placement may be made of cardiac

TABLE 3.—POLICIES OF THIRTY-FOUR CHICAGO INDUSTRIES (COVERING 395,084 EMPLOYEES) IN RELATION TO THE HEART CRIPPLE[1]

FIRM NUMBER	NUMBER OF EMPLOYEES	POLICY TOWARD APPLICANTS	POLICY TOWARD EMPLOYEES
1	9,500	Reject all. Possible exception for skilled workmen.	Find selected jobs.
2	3,500	Place only in skilled, non-hazardous work. Reject decompensated.	Find selected jobs. Make frequent reexaminations.
3	700	Make no discrimination. Work is light.	Make no reexaminations.
4	5,000	Accept compensated mitral cases for light work.	Make no reexaminations. Likely to discharge any found.
5	52,000	Accept compensated mitral defectives for clerkships or light work.	Make suitable adjustment when possible.
6	700	Employment office decides. Doctor makes no specific recommendations.	Retain, but work may not be suitably adjusted.
7	9,000	Reject all unless in positions hard to fill.	Retain in old position if possible. Work adjusted.
8	5,000	Reject all.	Place suitably if possible.
9	10,000	Reject all.	Place suitably.
10	7,400	Reject all.	Place suitably. Reexamine.
11	5,800	Reject for train service.	Do not discharge. Place suitably.
12	15,100	Reject all organic cases.	Give lighter work if not disabled; otherwise discharge.
13	1,000	Accept if able to do work applied for.	Place in suitable position.
14	8,000	Place favorable cases as clerks, draftsmen, etc.	Place in selected jobs.
15	2,500	Reject decompensated and borderline cases.	Place suitably. Reexamine.
16	400	Accept for posts not hazardous for patient.	Place in selected jobs.
17	27,000	Defect must not interfere with work. Find special work if good compensation.	Do not discharge.
18	1,000	Reject all.	Place some in selected jobs; discharge some.
19	27,000	Accept selected cases.	Place in selected posts. Pension fund for disabled.
20	3,500	Reject all.	Adjust suitably. Pension if disabled.
21	17,500	Reject all.	Retain. Supervise periodically. Demote in work and pay unless old and valuable employee.
22	6,000	Reject all.	Do not discharge. Give rest or light work.

[1] This tabulation includes transportation companies all of whose employees may not be resident in Chicago.

TABLE 3.—*Concluded*

FIRM NUMBER	NUMBER OF EMPLOYEES	POLICY TOWARD APPLICANTS	POLICY TOWARD EMPLOYEES
23	35,000	Reject all.	Place in selected jobs.
24	11,000	Accept selected cases for special work.	Place in suitable occupations.
25	42,700	Accept those with functional disorders only.	Select jobs and observe closely.
26	27,000	Reject all.	Place carefully.
27	1,500	Reject all.	Lighten work if possible, but not usually possible as work is rigorous.
28	8,000	Employ all well-compensated cases.	Retain and have treated by medical organization.
29	3,359	No data.	Supervise; 187 cardiac patients.
30	300	Reject if work is unsuitable for patient.	Adjust old employees. Make little effort for new employees.
31	14,575	48 rejections in 15,000 examinations.	Have 6 cases now, requiring close supervision.
32	50	Do not reject.	Make no adjustments. Regard heart cases with disfavor.
33	14,000	Make no examination before employment.	Find policy of light work with reduced pay not very effectual.
34	20,000	Reject all.	Make no adjustments.

workers. The flexibility seen here and there within industry in the matter of placement favors only the old and valued employee or the skilled worker on jobs difficult to fill. A relatively high proportion of the 155 jobs finally indexed as to their placement possibilities calls for skilled workers and apprenticeship periods. A worker who has remained untrained throughout his productive years is a rather discouraging prospect for reeducation, yet this is what remains to be accomplished if the situation is to be met in full. Retraining is not to be undertaken lightly, and in this connection it is well to remember that a patient who is well adjusted to rather heavy work is safer than one who is on lighter occupation but who is subject to sudden and unusual demands of energy output. It is of use to attempt to eliminate from certain jobs the few operations known to be particularly fatiguing to the cardiac worker.

The situation does not call for gratuitous criticism of the employer who, not knowing what to do, has done nothing. Nor does it help for social agencies to overrate the possibilities of the worker. The physician's responsibility likewise is to give reliable information regarding the type of handicapped person who may be considered a good risk under controlled conditions. It is useless for industry to feel that self-protection is obtained by a policy which excludes innocent murmurs but allows the rapidly disintegrating syphilitic hearts to pass. Rheumatic hearts, by far the most prevalent in age groups under 40, are better economic risks. Periodic tests of suspected cases are much better in-

TABLE 4.—CONDENSED ANALYSIS OF 155 JOBS IN VARIOUS PROCESSES IN FOURTEEN INDUSTRIES CO-OPERATING WITH THE CHICAGO HEART ASSOCIATION WITH A VIEW TO DEVELOPING SATISFACTORY JOB INDEXES FOR CARDIAC WORKERS[1]

NUMBER OF JOBS	PROCESSES	SKILLED OR UNSKILLED	SPECIAL TRAINING PERIOD	SPECIFIC ABILITIES	SEX	SALARY PER WEEK
7	Work in dental laboratory	Skilled	Variable, 4–5 yrs.	Accuracy	M–7	$10–$135
22	Manufacture of electrical apparatus	Unskilled	Short	Good eyes, dexterity	M or F–2 F–20	Piece rates
5	Making lamp shades	Both	Short	Dexterity, artistry	M–2 F–3	$18 up
11	Commercial photography	Both	Short in 7 processes	Dexterity, good eyes, experience	M or F–2 M–4 F–5	$15–$80
19	Office work	Graded	Variable	Education, experience	M or F–12 F–7	$12–$35
7	Paper box manufacture	Both	Train on job	Dexterity	M–1 F–6	$8–$16
6	Jewelry, and watch repair	Skilled Unskilled, 1	4–5 yrs.	Artistry, mechanical ability	M–6	$10–$90
5	Making artificial flowers	Unskilled	Short	Accuracy, dexterity, color sense	M–1 F–4	$6–$20
4	Beadwork embroidery	Skilled	Variable	Accuracy, dexterity	F–4	Piece rates
19	Woodworking	Unskilled	Experience, shop training	Deftness	M or F–4 M–11 F–4	Not stated

[1] All details of these studies are available to placement workers of the Chicago Heart Association.

TABLE 4.—*Concluded*

NUMBER OF JOBS	PROCESSES	SKILLED OR UNSKILLED	SPECIAL TRAINING PERIOD	SPECIFIC ABILITIES	SEX	SALARY PER WEEK
19	Printing and engraving	Skilled	Long apprenticeship	Interest, education, experience, strength	M or F-3 M-10 F-6	$8 up
22	Pencil and pen manufacture	Skilled, 18 Unskilled, 4	Train on job	Dexterity	M or F-3 M-6 F-13	Piece rates
4	Laundry	Unskilled	None	Strength	M-1 F-3	$13–$22
5	Miscellaneous	Both	Train on job	Not standardized	M-2 F-3	$13–$22

surance for the employer than sketchy initial physical examinations. The potential cardiac is safe only with careful diagnosis and in a safe position. The welfare of the employee is contingent entirely upon the science of shop management. Initial physical examination is not sufficient. The motion studies that are now becoming more prevalent can with very slight modification be made to include factors which would index every job suitable for the handicapped worker.

Chance, not Science, Controls

We have empirical medicine and we have a well-developed and fairly satisfactory empiricism in industrial management. The employees covered by this study include 100,000 at work on railroads; 56,500 in the steel industries; 48,000 in public utilities; 46,000 in the manufacture of electrical apparatus; 32,000 in department stores; 16,500 in mail order houses; and 96,000 in general manufacturing. Physical examinations are routine procedures only in hazardous occupations and in positions of trust. Positions popularly considered as light occupations are on actual test found to be taxing in the extreme. Fatigued men at strategic points who become irritable or inefficient should be scrutinized both as to their physical condition and as to work processes. Complete medical service with routine examination is most common in industries where the physical flotsam and jetsam drift. These safeguards are by no means universal in the heavier occupations and fatigue is not subject to routine tests.

This statement has included little about medical categories and the preventive aspects of heart disease. Nevertheless it is apparent that the best possible measure of protection is a public health program dealing with contagion, malnutrition, overwork, improper use of leisure, unhygienic

housing, and bad inheritance. The spotlight is turned upon industry because it is always under conditions of stress that imbalance develops, and it is our social habit to apply correction at that point rather than at the place of origin. Suggestions regarding the Chicago situation provide no universal formulae. It is well understood that specialization of work and motion study pertain to urban conditions, and everything hinges upon conscientious and general medical attention to this important problem. The untrained, undisciplined worker is a poor risk.

On the clinical side it should be said that perfectly satisfactory production has been consistently made by cardiac workers suitably supervised. The value of conservation in strategic positions and in highly skilled workers proves the general value of the principle. It has to be admitted in the face of these facts that heart disease for the most part goes undiagnosed until disaster impends. Heart defectives fall definitely into two large classifications: the one due to infections among persons under 40; and the other to hypertensions and other senile conditions. Perhaps 40 per cent. of all cases at all ages belong to the rheumatic group.

Rheumatism a Working Class Disease

While no such comprehensive study has been made of rheumatism in America as that covered by the recent British Medical Society report on environmental and other predisposing causes of rheumatic fevers, with its spot maps and occupational data, we may safely accept the general dictum that rheumatism affects the children of working classes in particular and that its prevention requires social as well as medical remedy.

Syphilis takes its toll in the younger groups. The older syphilitic nearly always meets a cardiac death. Only one of the industries surveyed expressed any opinion as to the desirability of routine Wassermann or precipitation tests. This opinion favored some specific diagnostic procedure to eliminate the syphilitic heart from among a certain group in hazardous positions in which the responsibility for the safety of others was great.

The syphilitic heart is of particular importance in the older age groups. An inactive systemic infection which has lain dormant for years may, when a man is older, take a virulent form of heart disease in the presence of overstrain, fatigue, or superimposed infections and intoxications. Medical categories are relatively simple in ages beyond 50. Medical correction, however, does not become correspondingly simpler, for the same intensive research has not been given the hypertensive groups that we are now devoting to primary causes of heart failure having their origin in infancy and childhood. Endocrine changes probably play a part, and environmental conditions are relatively more important as habits are fixed and the range of adaptability lessened. Pace setting is particularly important for the aging worker and due respect must always be given to individual rhythms, even to individual idiosyncrasies, and it is here that minute attention to the elimination of postural

strain and irregular and sudden demands conserves the old and valued employee. It is particularly in the older age groups that the newly developing insurance codes which make classification on the basis of physical findings rather than from diagnostic data are illuminating. The newer viewpoints in heart examination rely more definitely on objective findings in the patient and, with regard to placement, require tests to bring out the presence of breathlessness or discomfort which mark the physiologic limit of exertion. Some cardiologists recommend the use of the X-ray in doubtful cases in persons aged 50 years and over.

Prevention of rheumatism must concentrate on the school years between the ages of 5 and 15, and it is well to appreciate that the child who does not do well in open air classes is probably exhibiting the malnutrition and early anemia characteristic of the potential heart patient. The pretuberculous child is no more important to study than the precardiac. The rheumatic heart is good for from three to five times the length of service that the syphilitic heart is good for. Nevertheless, enthusiastic sponsors for the employment of cardiac defectives should realize that less than 31 per cent. of rheumatic hearts recover, and fully 50 per cent. die before the age of 40. Insurance experience shows that even so-called "functional" hearts show 50 per cent. increase over the expected mortality in age groups beyond 46 years. Dr. F. L. Grosvenor is responsible for figures recently submitted to the Insurance Medical Directors Association which are designed to measure the bearing of infections on the development of heart disease. Included as circulatory diseases were cerebral hemorrhage and apoplexy, pericarditis and acute endocarditis, organic disease of the heart, angina pectoris, and diseases of the arteries. The interesting fact was brought out from the 6,858 lives studied that the highest mortality in all cases of infectious origin took place in the younger age groups.

It is the so-called "innocent" lesion that is being elucidated by the joint mortality investigations of the British and American actuarial societies. The successive reports of these studies bring out the social grades of the population in which disabling heart conditions occur, and a habitat code now in preparation is expected to reveal the spots of unusually high incidence. Under their new medical categories the "innocent" mitral murmurs are placed in three medical groups instead of in one. A localized mitral murmur with no other impairment is of slight significance. If, however, the murmur is distinctly transmitted, the risk of heart disaster is decidedly increased. If in addition there is a history of rheumatic attacks, or of family incidence, the risk is more than doubled, the ratio being 106, 158, and 234 per cent., respectively, of the expected mortality. These figures are based upon New York Life Insurance Company experience, ratings which include only the most favorable groups, as none but functional disorders of the heart are accepted.

Classification of heart disease thus becomes possible along more scientific lines, and fewer guesses jeopardize the economic and physiologic welfare

in industry of the employee with defective heart. Internal adjustments of personnel are on the whole more satisfactory for the older age groups, but medically the hypertensive cases have not yet been segregated for the type of intensive clinical investigation which the extent of the problem demands.

Conclusions

1. The economic cost of heart disease mounts to an unmeasured degree under haphazard systems and exclusion policies, without careful medical examination and periodic physical tests.

2. Employee benefit systems appear to favor an unbiased consideration of health problems. Solution of work problems through retraining is the fond hope of amateurs; this method does not loom large in practical schemes.

3. Medical categories as such are less important in formulating heart problems in industry than are personality studies and performance tests. The Chicago Heart Association is right, therefore, in strengthening social service and in prosecuting further inquiry in the direction of tests which will sift out and favor the potential cardiac patient.

4. The fact that there are cardiac defectives who are unemployable in competitive jobs but who are still able to work calls for a state wide conservation program which will permit the economic and curative benefits of regular and remunerative work. Until workmen's compensation ceases to charge industry with undue responsibility with regard to heart defect, such a workshop will have to be sponsored by an outside agency under full co-operation and support of employers.

5. Scientific management, with its job indexes and its intensive study of individual workers, offers an excellent opening for corresponding performance indexes of handicapped workers. Placement work that is planned on a precision basis will be in better odor than haphazard employment methods as generally used at present.

6. Medical emphasis must be placed elsewhere than at the point of cardiac breakdown. The British method of providing arthritis units and hospital care for rheumatism as the most important cause of heart disease in age groups under 40 is a case in point.

7. Co-ordinated, continuous work with a definite objective through scientific groups similar to the Chicago Heart Association is to be credited with the development of a new health viewpoint and a new public health technic.

METAL FUME FEVER: III. THE EFFECTS OF INHALING MAGNESIUM OXIDE FUME*

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IN TWO previous papers, we have shown that a pronounced leukocytosis (1) is perhaps the most distinctive clinical feature of the metal fume fever acquired by the inhalation of freshly formed zinc oxide fume, and that, if a second inhalation is taken on the day following an attack of fever while the white blood cell count is still high, the subject enjoys a definite type of resistance (2).

It has been pointed out (3) that the cases of metal fume fever reported in the literature were generally caused by the inhalation of freshly formed zinc oxide fume. Up to that time (1922) it apparently had not been mentioned as occurring in men who handled zinc oxide powder. Since then Koelsch (4) reports that "cases have been observed, however, in which inhalation of ordinary zinc oxide in very finely divided powder form has produced symptoms similar to those produced by vaporization"—that is, by burning zinc vapor.

This observation has been confirmed in our experiments; for two of us had attacks of fever on inhaling finely grained zinc oxide powder, Kadox,[1] the particles of which were of the order of 0.4 micron in size. The Kadox had been dried overnight at 110°C. and while still hot was blown into our gas cabinet (1,600 cubic feet) by means of compressed air and a suction tee. In this way a well-dispersed cloud is produced which compares in stability with clouds formed from freshly burned zinc (5) and has approximately the same capacity for causing metal fume fever. After inhaling suspen-

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[1] Supplied by the New Jersey Zinc Company, Palmerton, Pa. The analysis is as follows:

	%
H_2O at 110°C.	0.369
Insoluble in HCl	0.015
CO_2	0.065
Total S as SO_3	0.002
Cl	0.001
PbO	0.072
CdO	0.013
Water soluble SO_3	0.001
Water soluble salts (dried at 110°C.)	0.045
Fe_2O_3	0.011
Bi_2O_3	under 0.001
CuO	under 0.001
MnO	under 0.001
As_2O_3	under 0.001
Sb_2O_3	under 0.001
ZnO (difference) approximately	99.400
Reducing power as SO_2	0.014

sions of this powder, one subject, A, recorded a maximum temperature of 100.4°F., and the other, C, a maximum of 101.2°F. In both cases, the general course of the fever and its after effects were precisely those resulting from the inhalation of freshly formed fume (1).

Koelsch (4) reports also cases of fume fever from the inhalation of finely divided copper oxide. He makes it clear that the symptoms were not similar to those caused by inhaling ordinary coarse copper dusts, but were like those experienced by brass casters after inhaling zinc oxide fume.

Inhalation of sprays of silver, copper, zinc, mercury, iron, cobalt, and antimony compounds may, according to Koelsch, bring about a rise in temperature. Moreover we now know of several instances of severe febrile reactions with marked prostration and abdominal pain, as well as nausea and vomiting, from breathing fumes from burned cadmium (6).

Iron, nickel, and aluminium can be burned readily in the electric arc. From our experience and from that of Koelsch, we should anticipate febrile reactions if the resulting fumes were inhaled, but the threshold dose of each would probably differ considerably.

The reason why zinc oxide powder and other metal fume products as powders rarely cause the fume fever in the paint, rubber, and other industries is, we believe, because they are often used wet and, even when dry, they are not easily dispersed and blown into the air.

Magnesium Oxide Experiments

For the experiments described in this paper we selected magnesium oxide fume. The reasons for this choice were several: (*a*) Magnesium occurs in the same group of the periodic table as mercury, cadmium, and zinc; (*b*) the formation of magnesium oxide from magnesium ribbon takes place with great vigor (3) and produces a fume with extremely small particles (7); (*c*) magnesium is one of the lightest metals known, having a density of 1.7, and cannot properly be considered a heavy metal; (*d*) magnesium is found in the ash of most foods, is ordinarily considered harmless, and is widely used in medicines; (*e*) magnesium oxide is insoluble except in acids.

Firms with experience in the use of flash light powders (consisting largely of magnesium) inform us that they have never noticed physiologic reactions from breathing magnesium oxide fume, although one firm remarked that it was customary to open the window after taking a flash light picture in order to let out the smoke.

There was sufficient evidence, in the case of zinc oxide, that occasional inhalations were not permanently injurious to man. In the case of magnesium oxide, we possessed no evidence; hence, before performing any experiments on men, we subjected cats (8) to dense fumes made by burning magnesium ribbons.[2] These experiments were made especially severe

[2] The ribbon, furnished by Howe and French, Inc., Boston, contained 0.014 per cent. SiO_2, 0.133 per cent. Fe + Al, and 99.853 per cent. Mg. (difference).

by adding about 10 per cent. of carbon dioxide (9) to the air. This caused the animals to breathe deeply and so insured penetration of the magnesium oxide particles into the alveolar spaces. The results of these experiments, compared with the results of former animal experiments (8) with (*a*) zinc oxide fume, (*b*) gas black, and (*c*) 10 per cent. of carbon dioxide in normal air, indicated that magnesium oxide would probably produce a fume fever in man of much the same type as that produced by zinc oxide, except that more severe exposures would be necessary. This is a conclusion which we were also led to expect from the position of magnesium in the periodic table.

TABLE 1.—PROTOCOL OF TWO EXPERIMENTS ON INHALATION OF MAGNESIUM OXIDE

DATE	SUBJECT	EXPOSURE	RESPIRATIONS	AIR BREATHED	AVERAGE CONCENTRATION OF MAGNESIUM OXIDE	MAGNESIUM OXIDE INHALED	PHYSIOLOGIC REACTION
		min.	*per min.*	*l.*	*mg./cu. m.*	*mg.*	
			Experiment I				
Nov. 8	A	4	6	27.0	5.8	16	Yes.
"	D	3	19	30.0	5.8	17	No.
"	C	2	12–15	18.0	5.8	10	Doubtful.
"	J	1	12–15	8.5	5.8	5	No.
			Experiment II				
Nov. 11	A	9	6 for 6 min. 12 for 3 min.	64.0	4.1	26	Yes.
"	D	7	18	70.0	4.2	29	No.
"	C	5	17	40.0	4.2	17	Yes.
"	J	3	12	34.0	4.3	15	No.

In the magnesium oxide experiments on man, three of the subjects, A, C, and D, had contracted fever from breathing zinc oxide fume on several former occasions; the fourth subject, J, had also inhaled fume but not in sufficient doses to produce the fume fever.

In order to generate magnesium oxide in our gas cabinet, we placed 30 gm. of magnesium ribbon about 20 cm. from the floor and ignited it by bunsen burner. A large part of the burned ribbon fell to the floor, but enough magnesium oxide was carried into the air to produce a comparatively stable cloud. Determinations of the suspension were made by electric precipitator—the precipitate titrated with 0.1N acids and alkalies—and the results checked by Tyndallmeter

(5). When the cloud had passed its maximum density and was gradually settling out, the four subjects entered the cabinet. Subject A sat down and breathed at the rate of 6 respirations a minute for four minutes; subjects D, C, and J, who remained standing, breathed at their normal rates and left the cabinet after exposures of three minutes, two minutes, and one minute, respectively. Although A actually inhaled less fume than D (Table 1), he breathed at a slower rate and much more deeply. As we have already pointed out (1) (2), slow, deep breathing is much more effective in producing the fever than is normal breathing. In this instance, for example, we consider A's exposure about three times more severe than D's. Of the four subjects, A was the only one who had a positive reaction from the first experiment, although C was conscious of a malaise.

TABLE 2.—SUBJECT A. CLINICAL SYMPTOMS FOLLOWING INHALATION OF MAGNESIUM OXIDE

TIME	NUMBER OF HOURS AFTER INHALATION OF MAGNESIUM OXIDE	TEMPERATURE	LEUKOCYTE COUNT	DIFFERENTIAL LEUKOCYTE COUNT					REMARKS
				Polymorphonuclears	Lymphocytes	Large Mononuclears	Eosinophils	Basophils	
		°F.	*per c. mm.*	%	%	%	%	%	
9:30 a.m.	....	98.5	7,100	69	23	6	1	1	In normal health.
10:30–10:39—inhalation of magnesium oxide.									
10:52	0.4	98.6	.....	..	..	..	..	..	No taste. Slight tracheal irritation.
12:15 p.m.	1.8	....	10,850	63	31	4	1	1	.....
1:30	3.0	99.0	.....	..	..	..	..	..	Slightly feverish, especially about the eyes.
2:00	3.5	....	9,700	67	29	3	1	0	.....
3:25	4.9	99.1	.....	..	..	..	..	..	Felt distinctly feverish.
3:45	5.3	....	15,650	77	16	6	0	1	.....
4:30	6.0	98.9	.....	..	..	..	..	..	Felt distinctly feverish.
5:00	6.5	....	15,150	76	16	5	2	1	.....
6:45	8.3	98.1	.....	..	..	..	..	..	Malaise.
10:00	11.5	98.4	10,900	68	24	6	2	0	Malaise. Slept soundly.
9:30 a.m.	23.0	....	6,150	56	37	5	0	2	Entirely recovered.
10:00	23.5	98.5	.....	..	..	..	..	..	.....

Three days later the experiment was repeated, with more severe exposures, as shown in the second part of Table 1. On this occasion, A's reaction was unmistakable; it is given in detail in Table 2 and illustrated graphically in

Figure 1. White counts and temperatures of the other three subjects

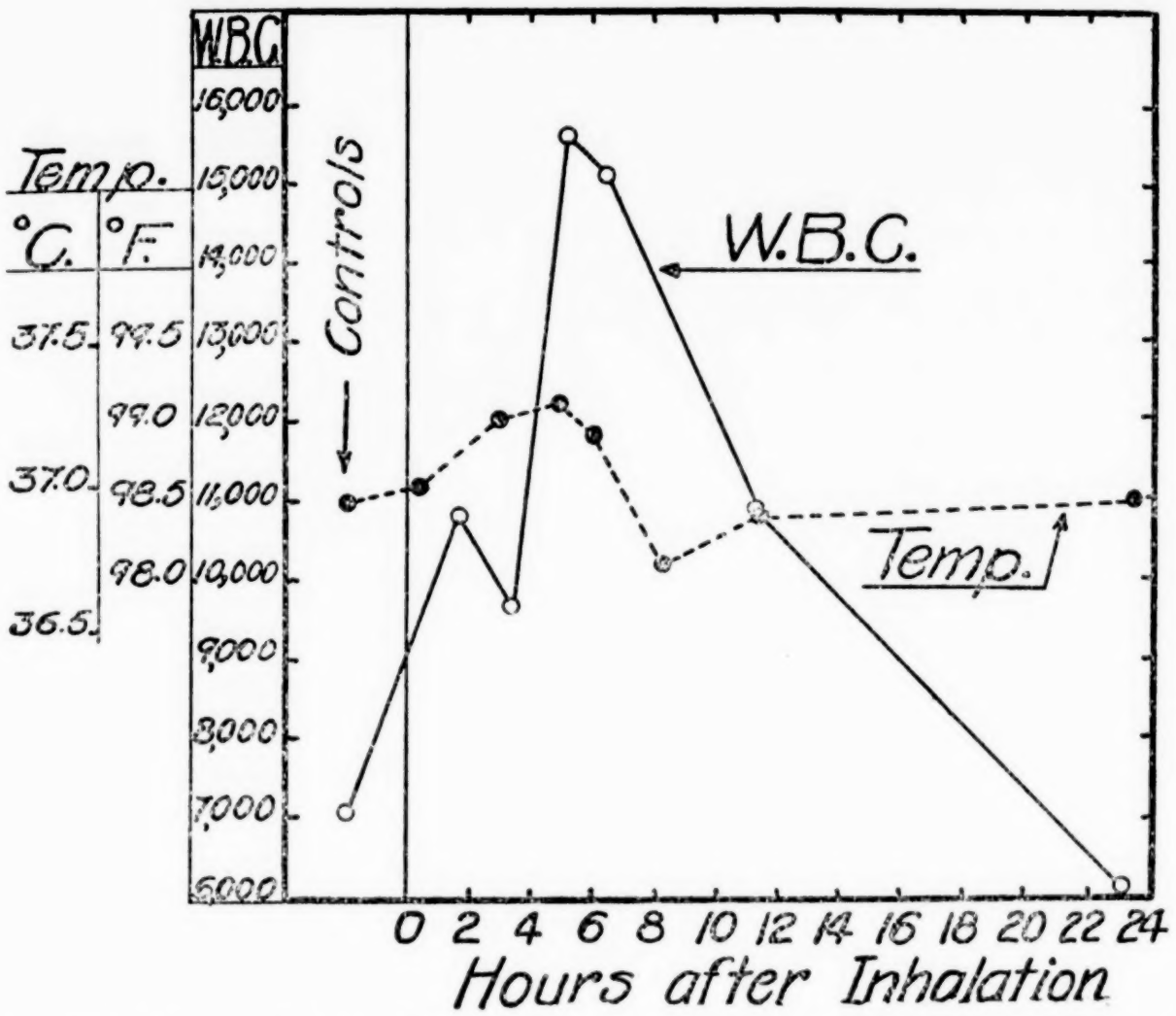

FIG. 1.—Subject A. White blood cell count and body temperature from the data of Table 2.

were taken in both experiments but, since they were not significant, they are not recorded. It should be noticed that the leukocytosis is due mainly to the increase in polymorphonuclear cells, just as in the case of fever from zinc oxide (1).

DISCUSSION

It is interesting to observe that subject A's maximum temperature and white count occurred about five or six hours after the inhalation. From zinc oxide inhalations, the maximum reactions, if definitely febrile, usually occur in eight to twelve hours (1). It is noticeable that, under microscopic examination, magnesium oxide particles have less tendency to aggregate and are, in general, smaller (7) than those of the zinc oxide we generated by blowing oxygen across the surface of boiling zinc (1) (2). This may explain the difference in reaction times after inhalation of zinc oxide and of magnesium oxide. As in the case of zinc oxide, it is probable that more severe exposures to magnesium oxide would alter the shapes both of the temperature and of the white cell count curves, especially the latter, but on this point we have no data. Severer exposures would doubtless produce severer reactions; but unless magnesium oxide fume should be encountered as an industrial hazard—and that seems unlikely—we see no reason for continuing these experiments on man.

The purpose of the experiments described was to show that a freshly formed metal fume product (not a compound of a heavy metal) which is ordinarily considered insoluble and physiologically inert would, if inhaled in sufficient quantity, produce a febrile reaction and a leukocytosis analogous to that caused by the inhalation of zinc oxide fume.

Summary

Instances of febrile reactions analogous to those caused by breathing freshly generated zinc oxide fume are reviewed. The substances mentioned include zinc oxide powder, copper (oxide?), sprays of compounds of silver, mercury, iron, cobalt, and antimony, and fumes from burned cadmium. It is probable that the fumes from the burning of iron, nickel, and aluminium in the electric arc would also cause the same general type of febrile reaction.

It was found that the inhalation of mild doses of magnesium oxide (a fume product of a light metal) generated by burning magnesium ribbon produces a leukocytosis and a fever resembling those caused by the heavy metals. Although magnesium oxide produces fume fever much less readily than does zinc oxide, it is believed that severer doses than those taken in these experiments would result in severer reactions.

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BASOPHILIC MATERIAL IN BENZOL POISONING: A PRELIMINARY REPORT*

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IN BENZOL poisoning three abnormalities have been associated with the blood. These are leukopenia (1) (2) (3), diminished platelet count (4), and lessened coagulability of the blood (5). Of the three, the test for leukopenia appears to be regarded as most valuable as a diagnostic sign. In many industrial institutions having a benzol hazard, the exposed workers are routinely tested for leukopenia at intervals. Absence of a leukopenia may give a sense of security that is unwarranted, for benzol poisoning of severe degree, either acute or chronic, may apparently occur without an attending leukopenia, and, in fact, in the presence of a leukocytosis. When exposure to benzol is limited to low concentrations, and at least in the early stages of response to higher concentrations, an irritant action appears to be exerted on blood forming tissues, particularly on the erythroblastic tissues.

In 1907, Langlois and Desbouis (6), employing small quantities of benzol as respirable vapors, observed an irritant action in guinea-pigs and pigeons, the action being less marked in rabbits and dogs. This irritation was manifest as a mild leukocytosis. In some instances the red blood cell counts were increased, to as much as 33 per cent. above normal.

Duke (4), in his platelet experiments, determined that the first few injections of benzol into animals brought about an increased number of platelets, followed by a rapid diminution.

This irritant action was noted in one of the early papers on benzol poisoning (1). Hamilton (7) summarizes Selling's animal experiments covering this phase of action, as follows:

> Selling's animal experiments had shown that benzene is a powerful leucotoxin, destroying the white cells of the circulating blood and the parenchymal cells of the blood-forming organs—bone-marrow, spleen, lymphatic glands, and the lymph follicles in the appendix—the myeloid tissue suffering more damage than the lymphadenoid and the polynuclear cells more than the lymphocytes. The erythroblastic tissue of the bone-marrow is destroyed, but the circulating erythrocytes are injured relatively little. The pathology of benzene poisoning is essentially an aplastic anemia. No nucleated reds or abnormal reds are found, platelets are absent or scanty, and there is polymorphonuclear leucopenia.

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Selling found that while benzene destroys the specific cells of the bone-marrow, causing extreme aplasia, there is at the same time an irritant action, and, for a while, the two actions go on simultaneously. If the injections are stopped at a point when the blood-forming organs are almost wholly aplastic, regenerative changes begin within a few days and are complete in ten days to three weeks, the blood picture also approaching the normal.

Similar evidences of the stimulant or irritant action of benzol on blood forming tissues are to be found in the works of Rabe and Hirschland (8), of Weiskotten, Schwartz, and Steensland (9), and in the report of the Committee on Benzol of the National Safety Council (10).

During the period (1912 to 1913) in which benzol was utilized therapeutically in leukemia, many reliable reports indicate a marked leukotoxic action for benzol associated with an increased count of red blood cells.

This irritant action has been investigated by us in the quest for simple laboratory procedures aiding the recognition of early benzol intoxication.

The red blood cells (erythrocytes) formed in bone marrow are normally thrust into the circulation when they become essentially mature. Under conditions in which the body has need for an increased number of red cells, *e.g.*, in anemia, or when the bone marrow is irritated by some toxic substance, immature red cells may be thrown into the blood stream from the bone marrow. Immature red cells may enter the blood stream in lead poisoning (11) as the result of irritation of the bone marrow by the lead. In primary anemias (12), these immature cells serve as a possible index for prognosis and a possible guide for transfusions. In the newborn (13), the number of these immature cells found in the blood stream is high.

There are many acceptable evidences of immaturity, ranging from the nucleated red cells to the Isaacs body (14), which is apparently lost as a last step prior to maturity. Between these extremes, a stage occurs in which all or a large number of the forming red cells contain basophilic material. This type of cell has been extensively studied by Key (15) under the designation "reticulated cells." McCord, Minster, and Rehm (11) have used the presence of these cells as evidence of imminent lead poisoning. In lead workers without clinical evidence of lead poisoning, basophilic material in a form termed by these investigators "basophilic aggregations" is frequently present. Such basophilic aggregations precede clinical lead poisoning and, when detected, permit anti-lead treatment prior to disability. It is probable that polychromatophilic cells are closely related to reticulated cells and to basophilic aggregations. Basophilic material in red cells is commonly regarded as evidence of regeneration.

If benzol serves as an irritant to those tissues forming the red cells, we may expect to find, under conditions of exposure to benzol, immature cells containing basophilic material in the blood stream in numbers exceeding normal.

Methods of Establishing Presence of Basophilic Material

Three technical procedures have been utilized in this work: (*a*) enumeration of red cells containing baso-

philic material; (*b*) basophilic aggregation test; (*c*) Wright's stain for polychromatophilic cells.

Enumeration of Red Cells Containing Basophilic Material

After cleansing the finger or the ear of the subject in the usual manner, and pricking, blood was drawn into the leukocyte tube of any good haemacytometer up to .5. Brilliant cresyl blue solution (0.25 per cent.) in normal saline solution was then drawn in until the mixture of blood and stain reached point 11 on the counting tube. The tube was shaken for about three minutes; then a drop was expressed on the ruled counting slide. With a DD Zeiss high dry lens, counts and computations were made as for leukocytes, the figure derived representing the total number of basophilic red cells per cubic millimeter. By this method the cells containing basophilic material in persons apparently healthy are usually below 1,000 cells per cubic millimeter.

In the literature on this subject the majority of counts of basophilic red cells have been made from stained slide preparations. In such a procedure 1,000 red cells are usually counted and the number of reticulated red cells within this number noted. Eight to ten such cells, per thousand red blood cells, are frequently regarded as representing normal numbers for apparently healthy persons. By extension of these figures it would appear that in 1 c.mm. of blood from a person having 5,000,000 red cells, there would be found 50,000 basophilic red cells. In our own hands this method has not proved entirely dependable. Different slide preparations made from the same patient at the same time have shown counts so varying as to be represented in the ratio of 1:4.

Cupp (16) has shown that through the action of certain chemicals all red blood corpuscles may be made to present reticulation, although it is not clear that this form of reticulation is the same as or is related to the basophilic reticulation frequently associated with anemias and with certain occupational diseases occurring without anemias. He concludes from his investigation of the structure of the erythrocytes of human beings and of other animal forms that the mammalian erythrocyte "normally possesses a framework in the form of a fine threaded, somewhat elastic reticulum in the meshes of which its hemoglobin is supported so intimately that its content partakes of the physical characters of gelatin;" and that the normal erythrocyte possesses a peripheral membrane "which is derived from and consists of a peripheral condensation or massing of the reticulum." Cupp states, with reference to the chemical character of erythrocytic reticulation, that his preparations seemed "to support the conclusion that the structures observed are not artefact, that the corpuscle is pervaded by a true reticulum, a network of threads joining each other and extending in all the planes of space;" he believes that the chemical composition may be that of a "nucleo-proteid" or cholesterin.

As a requisite for the observation of Cupp's normal reticulation it is necessary that the hemoglobin of the red blood cells be dissolved or otherwise caused to disappear. Some of the procedures utilized in studies of

basophilic reticulation lead to hemolysis of the red blood cells and thus may bring into visibility this possible, different form of reticulation described by Cupp. When, in the study of basophilic reticulation, erythrocytes are laked, a form of reticulation may be observed which is very closely similar to that described by Cupp. This form of reticulation is not observed when vital staining is carried out without demonstrable hemolysis. It is possible, therefore, that the marked discrepancies that have been obtained in different investigations of reticulated cells in human beings may in part be due to the inclusion, in reticular enumerations, of some cells showing Cupp's form of reticulation which have been brought into visibility through hemolysis.

When blood is spread out on slides, as in the preparation of blood smears, some hemolysis probably always takes place. This favors the development of reticulation; at any rate, reticulated cells in such preparations present a more clearly defined reticulation, with a wider distribution of reticulate material in the cell than is the case when vital stains are applied to cells within counting pipettes. When, therefore, we accept 1,000 basophilic red cells as representing the normal for apparently healthy persons, according to our method of enumeration, it is not our purpose at this time to deny that other methods may yield a higher count for reticulated red cells.

Friedlander and Wiedemer (13), using the polychrome methylene blue method, found in the new-born such counts of basophilic red cells as 18,000, 16,400, and 17,000 per cubic millimeter. After birth, the corresponding counts were 250, 10, and 10 such cells per cubic millimeter, on the eleventh, ninth, and ninth days, respectively. The highest count (28,400) reported by these authors and interpreted by them as representing basophilic red cells markedly increased over normal, for adults, is approximately one-half the figure (50,000) frequently suggested as representing the normal number of reticulated cells per cubic millimeter for human beings. These differences may perhaps be reconciled in part through the recognition of two types of reticulation, basophilic reticulation and Cupp's reticulation.

Later in this paper we include data showing blood counts obtained from benzol workers who were not suffering from benzol poisoning, in order to indicate the range of basophilic red cell counts for a person apparently healthy.

Basophilic Aggregation Test

The simple method used by McCord, Minster, and Rehm (11) in testing for imminent lead poisoning or lead absorption permits the collection of large numbers of blood specimens in the benzol workroom without difficulty, and without the necessity for any apparatus. In this procedure a blood smear, approximately three times the thickness of that in common use for differential counts, is made on a glass slide. This smear is unfixed and is air dried. Staining is secured by a dilute aqueous, acidulated methylene blue or by hypotonic saline methylene blue or through the use of dilute Manson's methylene blue. Staining is carried out for ten minutes. Overstaining does not occur. The excess stain is dashed off and the

slide is dipped in distilled water as few times as are necessary to remove the remaining stain. The slide is allowed to dry in air. Examination is made with an oil immersion lens, without any cover slip.

Microscopic examination presents the usual red cells as only faint shadows, except for the periphery which may be distinct. The white cells stain deeply and the various types may be differentiated. If there are red cells containing basophilic material, this material stands out sharply as coarse granules or as combined granules and network. This staining method appears to bring into greater visibility the very diffuse basophilic material seen in polychromatophilic cells.

If the blood smears so stained are of approximately the same thickness, a counting, for several fields, of the cells showing basophiiic aggregation affords a rough quantitative estimation as to the excess over normal. The normal person may, by this method, show only one or two basophilic red cells in an entire slide, while in lead poisoning every microscopic field may present ten or more basophilic red cells.

Since some hemolysis of the red cells takes place, the reticular forms described by Cupp (16) may be produced. For this reason this slide method is not highly regarded as a precise method for basophilic red cell enumeration.

Wright's Stain for Polychromatophilic Cells

Early in this study we depended on the presence of polychromatophilia for evidence of basophilic material in the red cells. It is our experience that wherever polychromatophilic cells are present other slide preparations will reveal equal or greater numbers of basophilic reticulated cells. There are some reasons to believe that the finely distributed granules which are common to polychromatophilia constitute the basic state of basophilic substance in red cells, and that basophilic reticulated cells, basophilic aggregations, mossy cells, punctate stippling, etc., are but different artefacts due to chemical manipulation. In an early series of cases of benzol poisoning in women, in which enumerations of basophilic reticulated cells were not made, we accepted well-defined polychromatophilia as some evidence of basophilic substance in the blood.

Experiments with Animals

Group 1. Rabbits

Control Rabbits.—Twelve rabbits believed to be normal, varying as to age, sex, weight, etc., were tested in order to determine the approximate normal count of basophilic reticulated cells. The counts resulting are recorded below:

Rabbit	*Basophilic Red Cells*[1] *per c.mm.*
1	21,000
2	56,000
3	51,000
4	48,000
5	11,800
6	85,000
7	68,000
8	53,000
9	23,000
10	26,000
11	14,000
12	18,000

[1] These figures are the average of several counts in each instance.

From these figures it appears that the reticulated cell count for rabbits, apparently normal, shows wide variation. So long as these animals remain normal, however, the individual reticulated count remains approximately the same. The counts obtained on nine successive days for a given rabbit, for example, are as follows:

Day	*Basophilic Red Cells per c.mm.*
1st	34,800
2nd	32,200
3rd	35,000
4th	36,200
5th	34,600
6th	34,000
7th	32,800
8th	36,000
9th	36,400

The red blood cell count for this rabbit was 5,200,000.

Rabbits Treated with Benzol.—Pure benzol was used for inhalations. The amount used was sufficient (10 to 15 c.c.) to narcotize the rabbit for about ten minutes. Inhalations were given in a small, tightly enclosed metal cage. Prior to exposure, blood counts were made daily for seven days in order to determine norms.

Rabbit 1.—Weight 1,725 gm. Before exposure to benzol, average blood counts were as follows:

	per c.mm.
Red blood cells	5,540,000
White blood cells	7,800
Basophilic red cells	14,200

Inhalations of benzol were given each day for ninety days, but after the fourteenth day, an additional inhalation was given on alternate days. When inhalations were limited to one daily, the basophilic red cell count dropped to 6,000. On increasing the amount of benzol inhaled (fourteenth day), basophilic red cell counts rose rapidly, as follows:

Day after Inhalation	*Basophilic Red Cells per c.mm.*
Start	14,200
12th	6,000
17th	40,000
21st	51,000
36th	48,000
49th	62,000
63rd	78,000
77th	91,000
84th	88,000
90th	90,000

On the ninetieth day the red blood cell count was 5,120,000.

Rabbit 2.—Weight 1,650 gm. Preliminary testing established average blood counts as follows:

	per c.mm.
Red blood cells	6,040,000
Basophilic red cells	53,000

Inhalations, as described for Rabbit 1, continuing for ninety-three days, were responsible for basophilic red cell counts as follows:

Day after Inhalation	*Basophilic Red Cells per c.mm.*
Start	53,000
14th	65,000
28th	80,000
42nd	120,000
56th	126,000
63rd	180,000
77th	190,000
91st	182,000
93rd	172,000

At no time did the red blood cell count vary appreciably, the count being 5,760,000 at the end of the experiment.

Rabbit 3.—Weight 1,800 gm. Preliminary testing established average blood counts as follows:

	per c.mm.
Red blood cells	5,560,000
Basophilic red cells	42,000

Inhalations, as described for Rabbit 1,

continuing for 100 days, brought about the following basophilic red cell counts:

Day after Inhalation	*Basophilic Red Cells per c.mm.*
Start	42,000
7th	40,000
21st	92,000
36th	102,000
49th	188,000
63rd	209,000
84th	198,000
91st	182,000
100th	186,000

No marked changes occurred in the red blood cell count throughout the experiment, the count being 5,480,000 on the ninety-seventh day.

Since the rabbit normally has so many basophilic red cells, and because in the rabbit these are so subject to variations, it was deemed advisable to supplement the results of our experiments with rabbits by experiments with other animals.

Group 2. Cats

Eight cats were tested in order to determine the normal number of basophilic red cells. The greatest number of such cells found was 200.

Results of experiments on two of the cats treated with benzol are as follows:

CAT 1.—Approximate weight 2,000 gm. Administration of ½ c.c. of benzol subcutaneously, every other day for thirty-seven days, produced the following results:

Date	*Basophilic Red cells per c.mm.*
June 14, 1926 (start)	none
" 18	200
" 22	400
" 28	2,000
" 30	2,400
July 7	3,800
July 14	3,200
" 20	2,800

The red blood cell count remained essentially the same throughout the experiment.

CAT 2.—Approximate weight 1,500 gm. Administration of ½ c.c. of benzol subcutaneously, every other day for thirty-one days, produced the following results:

Date	*Basophilic Red Cells per c.mm.*
June 10, 1926 (start)	none
" 14	800
" 18	2,000
" 20	1,400
" 24	3,600
" 28	3,800
" 30	3,600
July 5	4,200
" 10	4,000

The red blood cell count remained essentially the same throughout the experiment.

Group 3. Guinea-Pigs

Results of experiments on three guinea-pigs are here given:

PIG R. G.—Approximate weight 250 gm. Administration of ½ c.c. of benzol subcutaneously, every other day for twenty-six days, produced the following results:

Date	*Basophilic Red Cells per c. mm.*
Nov. 25, 1925 (start)	none
Dec. 4	1,000
" 7	5,000
" 9	1,600
" 10	12,000
" 14	9,000
" 16	11,000
" 20	14,000

PIG W. G.—Approximate weight 250 gm. Daily inhalations of benzol were given for twenty-six days and produced the following results:

Date	*Basophilic Red Cells per c.mm.*
Nov. 30, 1925 (start)	none
Dec. 4	4,800
" 7	2,200
" 8	1,600
" 10	1,600
" 11	8,000
" 14	14,000
" 18	15,000
" 25	18,600

PIG (tuberculous).—Approximate weight 250 gm. This pig had definite tuberculous glands. It was given ½ c.c. of benzol subcutaneously, every other day for seventeen days, with the following results:

Date	*Basophilic Red Cells per c.mm.*
June 28, 1926 (start)	12,800
" 30	20,000
July 9	21,800
" 12	20,000
" 14	29,000

From the results of the foregoing experiments, we conclude that the administration of pure benzol through inhalations, and through subcutaneous injections, leads to numbers of basophilic red cells far in excess of normal for the animals so treated.

Relation between High Basophilic Red Cell Counts and Regeneration of Red Blood Cells

Since some questions may arise as to the relation between high basophilic red cell counts and regeneration of blood cells, two rabbits were subjected to bleeding, and were studied in relation to basophilic red cell and red cell counts.

RABBIT 1B.—Approximate weight 1,480 gm. Average blood counts taken for three days before the experiment began established the following:

	per c. mm.
Red blood cells	5,520,000
Basophilic red cells	29,000

The data for bleeding experiments on this animal are given in Table 1.

RABBIT 2B.—Approximate weight 670 gm. Average blood counts taken for seven days before beginning the experiment established the following:

	per c.mm.
Red blood cells	5,120,000
Basophilic red cells	29,000

The data for bleeding experiments on this animal are given in Table 2.

CLINICAL STUDIES

The experiences here presented follow the order in which methods used for establishing the presence of basophilic material were described.

Experience 1

In a plant producing enameled leather, forty workers are exposed to the vapors of benzol and to direct contact with benzol through splashings on the hands and forearms. There is no artificial ventilation. About 300 pounds of benzol are evaporated hourly in two rooms which at times are superheated in order to favor evaporation. At one time, a single test, by the nitration method, showed 1,110 parts of benzol per million parts of air. Those persons painting hides by hand horizontally are grossly exposed to lacquers containing from 30 to 60 per cent. of benzol. No cases of benzol intoxication have arisen in this plant though conditions invited its occurrence. The hazard has existed in this plant for about eight years.

It was deemed desirable to test this group of apparently nonsusceptible workers. The blood counts are shown

TABLE 1.—DATA SHOWING RELATION BETWEEN HIGH BASOPHILIC COUNTS AND REGENERATION OF RED BLOOD CELLS IN BLEEDING EXPERIMENTS ON RABBIT 1B

DATE		RED BLOOD CELLS	BASOPHILIC RED CELLS
		per c.mm.	*per c.mm.*
Dec. 19, 1925	At 3 p.m. 36 c.c. of blood drawn from heart.		
	At 9 p.m. count taken.....	3,640,000	11,600
" 20	.....	3,240,000	19,400
	At 10 a.m. 20 c.c. of blood drawn from heart.		
	At 3 p.m. count taken.....	1,320,000	25,600
	At 9 p.m. 20 c.c. of blood drawn from heart.		
" 21	.....	760,000	20,400
" 22	Rabbit gave birth to 6 young; all born dead.....	1,560,000	92,800
" 24	.....	2,080,000	90,000
" 26	.....	3,520,000	108,000
" 29	.....	3,960,000	140,000
Jan. 3, 1926	.....	4,080,000	93,120

TABLE 2.—DATA SHOWING RELATION BETWEEN HIGH BASOPHILIC COUNTS AND REGENERATION OF RED BLOOD CELLS IN BLEEDING EXPERIMENTS ON RABBIT 2B

DATE		RED BLOOD CELLS	BASOPHILIC RED CELLS
		per c.mm.	*per c.mm.*
Jan. 16, 1926	At 10 a.m. 25 c.c. of blood drawn from heart.		
	At 7 p.m. count taken.....	2,360,000	39,400
	About 20 c.c. of blood drawn.		
" 18	.....	2,160,000	52,000
" 20	.....	2,760,000	70,800
" 22	.....	3,200,000	104,000
" 24	.....	3,440,000	120,000
" 26	.....	3,960,000	159,000
" 28	.....	3,720,000	204,000
Feb. 7	.....	4,320,000	180,000
" 14	.....	4,480,000	162,000

in Table 3. In these apparently non-susceptible workers, where scant leukotoxic action is noted, there is also scant irritant action as evidenced in basophilic red cell counts.

Experience 2

In a certain factory, spray painting of metal cabinets was carried out, without using benzol. There came a

time when the process was changed to include benzol as a solvent. The inadequate booths were not bettered, however, to meet the increased hazard. Ten days after the new process was instituted, a night sprayer fell unconscious. Some details of his case are here noted:

TABLE 3.—DATA SHOWING BLOOD COUNTS OF THIRTY-THREE APPARENTLY NONSUSCEPTIBLE WORKERS EXPOSED TO BENZOL

WORKER	LENGTH OF EMPLOYMENT	HEMOGLOBIN	WHITE BLOOD CELLS	RED BLOOD CELLS	BASOPHILIC RED CELLS
		%	*per c.mm.*	*per c.mm.*	*per c.mm.*
F. B.	3 yrs.	90	6,800	5,040,000	800
W. K.	8 yrs.	80	10,400	4,440,000	2,400
J. H.	2 mos.	90	9,400	5,132,000	400
W. H.	6 mos.	85	7,200	4,520,000	200
O. P.	9 mos.	85	8,800	4,640,000	.....
E. B.	3 wks.	90	10,800	4,940,000	400
E. C.	8 mos.	90	9,800	5,360,000	200
A. G.	11 yrs.	90	7,800	5,640,000	400
F. G.	7 mos.	95	10,200	5,240,000	.....
G. N.	11 yrs.	85	7,400	5,320,000	200
W. C.	7 yrs.	85	9,400	4,960,000	1,800
E. M.	3 mos.	90	10,400	4,880,000	200
G. M.	26 yrs.	90	13,600	4,920,000	3,400
A. A.	4 yrs.	80	7,600	4,600,000	.....
A. V.	4 wks.	75	6,800	4,360,000	600
G. G.	31 yrs.	85	8,200	4,400,000	800
M. H.	25 yrs.	80	6,600	4,240,000	600
W. S.	12 yrs.	90	7,800	5,160,000	600
F. W.	7 yrs.	80	9,800	4,480,000	400
E. S.	26 yrs.	80	6,800	4,320,000	200
G. S.	5 yrs.	80	8,200	4,840,000	400
E. V.	4 mos.	90	9,400	4,600,000	600
D. H.	3 yrs.	80	7,200	4,400,000	200
C. L.	18 yrs.	80	6,800	4,320,000	1,600
S. M.	18 yrs.	85	8,200	4,560,000	.....
J. W.	1 yr.	80	9,800	4,480,000	600
J. T.	8 yrs.	80	8,800	4,360,000	400
M. P.	24 yrs.	90	6,800	4,520,000	600
R. Q.	4 yrs.	80	7,000	4,640,000	200
S. D.	10 yrs.	85	6,600	4,680,000	400
P. H.	5 yrs.	80	6,200	5,200,000	200
N. F.	23 yrs.	75	6,400	4,040,000	200
A. R.	10 yrs.	80	10,600	4,680,000	400

H., a man aged 24, engaged in spraying paint for some time, had never suffered from any occupational disease until he was changed to spraying a new kind of paint containing benzol and various acetates. He was overcome by fumes on Nov. 25, 1924. On the following day he developed some nausea and fainting attacks, with tachycardia, epistaxis, conjunctivitis and

pharyngitis, and, later, severe bronchitis, with marked inflammation of all of the accessory nasal sinuses.

Blood Examination.—Examination of the blood on Dec. 10, 1924, showed:

	per c.mm.
Red blood cells	4,770,000
White blood cells	13,000
	per cent.
Hemoglobin	90.0
Differential leukocyte count:	
Polymorphonuclears	78.7
Small mononuclears	11.0
Large mononuclears	3.1
Transitionals	5.8
Eosinophils	1.2

Smear taken for basophilic red cells showed a basophilia of 4 plus (*i.e.*, 4 cells containing basophilic aggregations in approximately every microscopic field (11)).

Urinalysis.—Examination of the urine showed: specific gravity, 1.032; reaction, acid; color, clear light yellow; albumin, trace; sugar, negative; acetone and diacetic acid, negative; occult blood and enormous number of white blood cells present.

In this case of benzol poisoning with a leukocytosis, the basophilic aggregation test was of value.

Experience 3

In still another factory the process involving benzol was the spray painting of small metal novelties. This was carried on in booths measuring about 3 by 4 feet. These were not well constructed, but no benzol poisoning occurred among the young women who were doing the spraying until an order came through which involved the spraying of large parts, approximately the size of a writing desk. Since the booths were too small, spraying was done in the open room without any protection. At the end of ten days eight women presented evidence of benzol poisoning. Three were bleeding; one from the respiratory tract, two from the uterus. In the blood counts listed below for these eight cases, evidence of irritation is limited to the finding of well-established polychromatophilia and nucleated red cells in seven cases. These cases were the initiating factors in our study of basophilic material in benzol poisoning. The leukopenia and the lengthened clotting time are noteworthy.

Case 1.—E. O., female, aged 19 years, entered employment as spray painter in work involving exposure to benzol, on Sept. 17, 1925. For about one week prior to Oct. 16, 1925, exposure was increased through the fact that spraying was carried on in an open room, because the booths were too small to accommodate the work. On Oct. 16, 1925, the patient began to bleed from the uterus, although the menstrual period was not due. The bleeding was associated with a marked weakness.

Blood Examination.—On the 18th of October, laboratory examination of the blood revealed:

	per c.mm.
Red blood cells	3,240,000
White blood cells	6,200
	per cent.
Hemoglobin	60
Differential leukocyte count:	
Polymorphonuclears	69
Small mononuclears	22
Large mononuclears	6
Transitionals	2
Basophils	1
Eosinophils	0

Clotting time was five and one-half minutes. Nucleated red cells were found, together with polychromatophilia.

On Oct. 20, 1925, this patient's blood count was again taken and revealed the following:

	per c.mm.
Red blood cells	3,520,000
White blood cells	5,600
	per cent.
Hemoglobin	65
Differential leukocyte count:	
Polymorphonuclears	67
Small mononuclears	23
Large mononuclears	8
Transitionals	2
Eosinophils	0

Nucleated red cells were found, together with polychromatophilia.

The severity of this condition did not increase, and by the latter part of November, the patient was certified for work that did not involve exposure to benzol.

CASE 2.—N. L., female, aged 35 years, entered employment in the spray painting department in April, 1924, and was forelady, in the middle of October, when the spray painting was carried on in an open room without protection. The patient's abnormal condition started on Oct. 12, 1925. On Oct. 18, 1925, she complained of respiratory distress, gastric irritation, and loss of appetite.

Blood Examination.—Examination of the blood on October 18 revealed:

	per c.mm.
Red blood cells	3,280,000
White blood cells	3,800
	per cent.
Hemoglobin	60
Differential leukocyte count:	
Polymorphonuclears	62
Small mononuclears	29
Large mononuclears	5
Transitionals	3
Eosinophils	1

Clotting time was nine minutes. Nucleated red cells were present, together with polychromatophilia.

On Oct. 20, 1925, this patient's blood count was again taken, and revealed:

	per c.mm.
Red blood cells	3,320,000
White blood cells	6,600
	per cent.
Hemoglobin	65
Differential leukocyte count:	
Polymorphonuclears	67.3
Small mononuclears	23.4
Large mononuclears	6.1
Transitionals	2.0
Eosinophils	1.0

Nucleated red cells were found, together with polychromatophilia.

Notwithstanding our advice to this patient as to the probable severity of her condition, she immediately returned to the same work. We are advised that she has recovered completely.

CASE 3.—L. D., female, aged 31 years, began work as spray painter in September, 1925. About one week prior to Oct. 18, 1925, the exposure to benzol was increased through the fact that the spray painting was carried on in an open room with no protection. On Oct. 18, 1925, the patient was examined. She had no definite complaints.

Blood Examination.—The blood count revealed definite findings:

	per c.mm.
Red blood cells	3,400,000
White blood cells	3,200
	per cent.
Hemoglobin	65
Differential leukocyte count:	
Polymorphonuclears	60
Small mononuclears	32
Large mononuclears	5
Transitionals	2
Eosinophils	1

Nucleated red cells were found, together with polychromatophilia.

On Oct. 20, 1925, the blood count was again taken, and revealed:

	per c.mm.
Red blood cells	3,360,000
White blood cells	3,400
	per cent.
Hemoglobin	65
Differential leukocyte count:	
Polymorphonuclears	58.5
Small mononuclears	31.3
Large mononuclears	7.1
Transitionals	2.0
Eosinophils	1.0

Nucleated red cells were found, together with polychromatophilia.

After one week's absence, this patient returned to the same work.

CASE 4.—L. H., female, aged 23 years, began work March 1, 1925, as spray painter. Two or three days prior to Oct. 13, 1925, the exposure to benzol was increased through the fact that spray painting was carried on in an open room without protection. On Oct. 13, 1925, the patient developed an abdominal pain in the stomach region, shortness of breath, sore throat, dizziness, spitting up of blood (about ½ cupful), frequent urination, etc.

Blood Examination.—This patient's blood was examined on October 18, and revealed:

	per c.mm.
Red blood cells	4,040,000
White blood cells	6,400
	per cent.
Hemoglobin	70
Differential leukocyte count:	
Polymorphonuclears	77
Small mononuclears	20
Large mononuclears	3
Transitionals	0
Eosinophils	0

Clotting time was three minutes.

On Oct. 20, 1925, this patient's blood was again examined, and revealed:

	per c.mm.
Red blood cells	4,120,000
White blood cells	6,500
	per cent.
Hemoglobin	70
Differential leukocyte count:	
Polymorphonuclears	60
Small mononuclears	27
Large mononuclears	11
Transitionals	1
Eosinophils	1

This patient was disabled for about one week, then resumed work in another occupation.

CASE 5.—E. E., female, aged 40 years, began work as a spray painter July 7, 1924. This patient's disability apparently began prior to the time of increase in exposure to benzol owing to the fact that spray painting was carried on in the open room. On Oct. 4, 1925, the patient developed abdominal pain, dizziness, nausea. No other symptoms developed.

Blood Examination.—Blood count was made on October 18, which showed the following:

	per c.mm.
Red blood cells	3,440,000
White blood cells	4,200
	per cent.
Hemoglobin	55
Differential leukocyte count:	
Polymorphonuclears	66
Small mononuclears	25
Large mononuclears	4
Transitionals	4
Eosinophils	1

Nucleated red cells were found, together with polychromatophilia.

On Oct. 20, 1925, this patient's blood count was again taken, as follows:

	per c.mm.
Red blood cells	3,680,000
White blood cells	4,800
	per cent.
Hemoglobin	60
Differential leukocyte count:	
Polymorphonuclears	68.6
Small mononuclears	23.2
Large mononuclears	5.1
Transitionals	2.0
Eosinophils	1.0

Nucleated red cells were found, together with polychromatophilia.

This patient lost about one week from her work and completely recovered.

CASES 6, 7, 8.—Three other women from the same factory submitted to blood counts.

Blood Examination.—Blood counts presented findings as follows:

(Case 6.)	*per c.mm.*
Red blood cells	4,020,000
White blood cells	3,800
	per cent.
Hemoglobin	85
Differential leukocyte count:	
Polymorphonuclears	67
Small mononuclears	20
Large mononuclears	11
Transitionals	2
Eosinophils	0

(Case 7.)	*per cmm.*
Red blood cells	4,520,000
White blood cells	5,800
	per cent.
Hemoglobin	90
Differential leukocyte count:	
Polymorphonuclears	64
Small mononuclears	22
Large mononuclears	10
Transitionals	2
Eosinophils	2

(Case 8.)	*per c.mm.*
Red blood cells	4,080,000
White blood cells	5,800
	per cent.
Hemoglobin	70
Differential leukocyte count:	
Polymorphonuclears	73.7
Small mononuclears	22.2
Large mononuclears	3.0
Transitionals	1.0
Eosinophils	0.0

In all three cases nucleated red cells were found, together with polychromatophilia.

These three women refused further co-operation and continued to work, and, we believe, suffered no severe consequences. One of these workers is said to have developed uterine hemorrhage. The hazard in this factory was lessened through the installation of a good type of booth.

Experience 4

J. S., male, aged 61 years, was a painter by trade. Past history and family history are without significance except that forty-four years ago he suffered from lead poisoning.

During 1925, this painter was engaged in the mixing of paint, in which he states he utilized a large amount of benzol in various preparations. Apart from paint mixing, he, himself, painted, usually in closets and in small rooms. In the latter part of December, 1925, he complained of attacks of dizziness, pain in the lumbar region, slight abdominal cramps, considerable loss of weight and strength, and a rapid development of pallor. This condition was associated with the occurrence of many red blotches in the skin, on the back and on the right thigh, varying from tiny petechiae to hemorrhagic areas the size of a twenty-five cent piece. Patient stated that these spots became purple, then blue and yellow, like a bruise. Although he was in considerable discomfort, the patient kept at work until Jan. 15, 1926. At that time there was a marked irritation of mucous membranes. The patient was acutely ill from this respiratory disease for several days, when, according to his family physician, he developed pneumonia. At about this time a recurrence of purpuric spots took place, principally on areas below the waistline. The patient became extremely emaciated and weak. Concomitant with this, he developed myocarditis and severe chronic bronchitis.

This patient was first seen by us five months after the onset of the disease. Our examination confirmed myocarditis, severe bronchitis, extreme emaciation, and depletion. Previous to that time no blood examination had been made.

Blood Examination.—Our blood examination revealed:

	per c.mm.
Red blood cells	3,370,000
White blood cells	24,000
Basophilic red cells	11,000
	per cent.
Differential leukocyte count:	
Polymorphonuclears	71.2
Small mononuclears	23.7
Large mononuclears	3.5
Eosinophils	1.5

Evidence suggesting that this is a case of benzol poisoning is limited to the patient's history of exposure and to the occurrence of purpura. The myocarditis and chronic bronchitis are logical sequelae of benzol poisoning. The high leukocyte count of 24,000 is probably attributable to infection associated with the chronic bronchitis. The absence of leukopenia would tend to deter a diagnosis

of benzol poisoning were it not for the clear-cut history. The high basophilic red cell count of 11,000 per cubic millimeter suggests that irritant action may not be limited to the early stages of benzol intoxication, but may in some instances continue in prolonged, chronic disabilities resulting from this intoxicant.

Comment

The presence of basophilic material in red blood cells in quantities exceeding normal is reported in animals (cats, rabbits, and guinea-pigs) to which benzol has been administered. Animal experiments without benzol administration, but with bleeding, afford some evidence that this basophilic material is associated with regeneration of the red blood cells.

Results of examinations of the blood in a number of cases of benzol poisoning, too few to warrant any conclusions, suggest that basophilic substance in quantities above normal occurs in the blood of human beings affected by benzol.

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VENTILATION OF VEHICULAR TUNNELS

PART I. AMOUNT AND COMPOSITION OF EXHAUST GASES FROM MOTOR VEHICLES IN RELATION TO THE VENTILATION OF VEHICULAR TUNNELS. *A. C. Fieldner, A. A. Straub, and G. W. Jones. Jour. Am. Soc. Heating and Ventil. Eng., Jan., 1926, vol. 32, pp. 17–36; Feb., 1926, pp. 79–100.*

This part is an abstract from Appendix No. 3, Tunnel Gas Investigations, Amount and Composition of Automobile Exhaust Gases, by A. C. Fieldner, A. A. Straub, and G. W. Jones, in Report of New York State Bridge and Tunnel Commission, 1921, pp. 91–140. It is summarized as follows:

The road tests on 101 motor vehicles for the purpose of determining the amount and composition of motor exhaust gas from automobiles and trucks of various sizes when operated on grades and at speeds similar to those that will prevail in vehicular tunnels have shown that:

1. The exhaust gas composition of individual machines varies greatly, and that the controlling factor is the air-gasoline ratio produced by the carburetor adjustment.

2. The percentage of CO for the majority of cars lies between 5 and 9 per cent.

3. The average percentage of CO for the first 23 cars tested was 6.7 per cent, which is practically the percentage of CO corresponding to an air-gasoline ratio of 12.4 ratio for developing maximum power.

4. The average percentage of CO for each class of vehicles under various conditions of test is given in tables and curves.

5. The average quantity of CO for each class of motor vehicles under certain conditions is given in tables and curves.

6. The combustible gas in the average automobile exhaust from one gallon of gasoline amounts to 30 per cent of the total heat in a gallon of gasoline.

7. The great majority of motor cars and trucks are operated on rich mixtures suitable for maximum power but very wasteful from the standpoint of gasoline economy.

8. On the average, carburetors are set in the winter and not changed in the summer, as shown by the higher percentages of CO found in the summer tests.

9. The largest quantity of CO will be produced in the 3 per cent grade sections of the tunnel. The CO produced under summer conditions is somewhat greater than in winter conditions. Summer tests should be used in computing ventilation of tunnels, owing to the tunnel becoming heated from the hot exhaust gases.

PART II. PHYSIOLOGICAL EFFECTS OF EXHAUST GASES FROM MOTOR VEHICLES. *Y. Henderson, H. W. Haggard, A. L. Prince, and M. C. Teague. Ibid., March, 1926, pp. 153–158.*

This part comprises excerpts from Appendix No. 4, Tunnel Gas Investigations, Problem No. 2, Physiological Effects of Exhaust Gases, by Y. Henderson, H. W. Haggard, M. C. Teague, A. L. Prince, and R. M. Wunderlich, in Report of New York State Bridge and Tunnel Commission, 1921, pp. 141–220. (See also THIS JOUR., 1921–1922, vol. 3, pp. 79, 137.)

OBSERVATIONS IN LARGE GASSING CHAMBER. *H. W. Haggard. Ibid., April, 1926, pp. 289–290.*

COMBINATION OF CARBON MONOXIDE AND HEMOGLOBIN AND ITS ANALYTICAL APPLICATIONS. *A. L. Prince. Ibid., pp. 290–291.*

CHARACTERISTICS OF THE CARBON MONOXIDE DISSOCIATION CURVE AND THE EXTENT OF INDIVIDUAL VARIA-

TIONS. *A. L. Prince. Ibid., pp. 291–294.*

DETERMINATION OF CARBON MONOXIDE IN AIR CONTAMINATED WITH MOTOR EXHAUST GAS. *M. C. Teague. Ibid., pp. 294–300.*

This is an excerpt from Report of New York State Bridge and Tunnel Commission, reprinted in *Industrial and Engineering Chemistry*, 1920, vol. 12, pp. 964–968.

PART III. TESTS CONDUCTED IN VEHICULAR TUNNEL IN EXPERIMENTAL MINE. *J. W. Paul, A. C. Fieldner, and R. R. Sayers. Ibid., May, 1926, pp. 387–404; June, 1926, pp. 479–486.*

This part treats of the results obtained during tests conducted in the experimental vehicular tunnel in the Bureau's Experimental Mine at Bruceton, Pa., to determine the relative merits of various methods of transverse ventilation by the relative diffusion of the carbon monoxide of exhaust gases, and of the check thereby obtained on various features of the preceding investigations.

. . . . .

Construction of the underground test tunnel as an entirely closed oval made it possible to control accurately the ventilation, and avoid the disturbance of air currents from open ends such as would be present in a straight tunnel section. It also made it possible to run automobiles continuously at a uniform speed for any desired period.

By constructing the tunnel underground, observations could be made on the flow of heat through the walls of the tunnel under conditions approximating those of the Holland tunnel, and thus obtain data for estimating the probable temperature rise produced in proposed underground vehicular tunnels.

. . . . .

. . . . The air requirements of the Holland tunnel were based upon . . . . theoretical calculations made from results of tests on 101 automobiles and trucks (Part I). The experimental test tunnel afforded a means of checking the reliability of these calculations.

Tests were conducted with four methods of transverse ventilation, with air currents discharging into and escaping from the tunnel. These methods were (*a*) upward flow, center outlets; (*b*) upward flow, side outlets; (*c*) downward flow, side outlets; and (*d*) downward flow, corner inlets.

The results of the tests show that the four methods of transverse ventilation tried are practicable for tunnel ventilation, and that upward ventilation with outlets in the center of the ceiling would require the least amount of air and less power for ventilation than the other three methods.

. . . .

The determination of heat flow from temperature measurements made in the test tunnel shows that the capacity of concrete walls for cooling tunnel air depends more essentially upon the diffusivity of the concrete than upon its thermal conductivity alone. This fact is very pertinent to the problem of removing excess heat from the air in the Holland tunnel, for it means that the cooling capacity of the walls, which has been accumulating during cool days, during the night, and at times of little traffic, is available to take care of peak temperatures lasting from a few hours to several days.

PART IV. DETAILS OF TESTS IN VEHICULAR TUNNEL IN EXPERIMENTAL MINE.

APPENDIX A.—CAR OPERATION AND PRODUCTION OF CARBON MONOXIDE. *G. W. Jones and H. C. Howarth. Ibid., Aug., 1926, pp. 617–627.*

This appendix covers special features regarding (1) car operation; (2) methods and procedure for liberating definite quantities

of carbon monoxide into the experimental tunnel atmosphere per hour; (3) a correlation of this data with previous road tests reported in Part I; and (4) results relative to the method of ventilation whereby the concentration of CO is kept at a minimum in the central part of the tunnel—that is, the ventilating method which gives the lowest concentration of CO in the driver's position when a given quantity of CO is liberated in a tunnel per unit time.

APPENDIX B.—AIR MEASUREMENT AND AIR DISTRIBUTION. *A. A. Straub. Ibid., Sept., 1926, pp. 658–663.*

Air Quantities. Calculation of the quantity of air required to be supplied with the different number of cars operating was based on the results of previous tests, which indicated that a car of the type used would produce 50 cu. ft. of CO per hour, and that sufficient air must be supplied to maintain the concentration of CO at 4 parts per 10,000 of air. It was found later that the quantity of air had to be increased, because of production of large quantities of CO by cars when operating along the guide rails of the tunnel roadway.

Air-measuring stations were built of approximately 20 sq. ft. area of section, at which points the velocity heads were measured. The velocity of the air passing the air-measuring stations, when a definite quantity of air was passing the definite area of section at the air-measuring stations, was determined. . . . .

. . . . .

Air-Measuring Instruments. Velocity heads were measured with a Wahlen gage (Illinois differential micrometer), which is capable of adjustment for variation in heads of 1/10,000 in. of alcohol; however, under conditions of these tests reliable data could not be observed on changes in head of less than 5/10,000 in. of alcohol.

As the instrument (as well as the observer) for measuring velocity heads was in an air-measuring station that adjoined the airway and communicated with it by means of a vertical slot at the measuring plane, the open end of the gage was subject to the static pressure of the air, and the impact tube used gave the velocity head readings direct. The impact tube was made of brass tubing ($\frac{1}{4}$ in. outside and $\frac{3}{16}$ inside diameter), bent at right angles with a 4-in. projection beveled to knife edge for $\frac{3}{4}$ in. back from the open end of the tube. When using the impact tube, this 4-in. portion was pointed directly against and parallel with the stream of air flow. The other data necessary to the calculation of the air quantity were: (1) barometer at station No. 1; (2) psychrometer readings at both stations; and (3) the temperature of the air surrounding the Wahlen gages; this last was necessary to the computation of the specific gravity of the liquid in the gage, and transformation of the velocity head in alcohol to equivalent heads in inches of water at 60 deg. fahr.

A brief account is also given of the use of air velocity measurements as a guide in the adjustment of dampers to produce uniform air flows.

APPENDIX C.—AIR CONDITIONS IN TEST TUNNEL. *G. E. McElroy. Ibid., pp. 663–672.*

During the series of tests conducted in the test tunnel, many readings of temperature, humidity, and air motion were made; and the effect of these features of the air conditions on the personal comfort experienced during test periods at two positions was determined by personal observation, and checked against kata-thermometer determinations of the cooling power of the air.

These data, taken by various observers and in various ways, were compiled to serve as a record of the conditions of tests and as a basis of study to determine the relative distribution and amount of the separate features for various changes in other test conditions, but more especially for changes in the method of ventilation.

. . . . .

. . . . Under the test conditions the horizontal air velocity induced by the moving cars was the controlling factor in deter-

mining the relative temperature and degree of comfort at various points in the tunnel, or within any cross section of it. With the cars moving at a constant rate, more or less stable conditions were attained throughout the tunnel, but as soon as the cars stopped, effects were localized.

(The author does not imply that this will be true in the Holland tunnels where the width of the driveway and clearance are proportionately greater than in the Bureau of Mines experimental tunnel.)

APPENDIX D.—SMOKE DENSITY MEASUREMENTS OF TUNNEL ATMOSPHERES. *G. R. Greenslade. Ibid., pp. 672–674.*

A Morse type optical pyrometer equipped with a green-stained gelatin filter was focused on a standard source of light situated at a point 50 feet away.

The optical pyrometer contained the usual comparison lamp which could be heated and controlled by means of a battery, a variable resistance, and a milliammeter. It was further equipped with a set of 12 black, brass, motor-driven, rotating sectors of various angular apertures which could be rotated between the objective lens and the comparison lamp. Thus, by interchanging these sectors, the intensity of the light coming from the standard source could be reduced by twelve definite percentages, the magnitude of the percentage of absorption of a particular sector being proportional to the ratio of the angle of its opaque part, to the entire angular circumference.

Before each test, the apparatus was calibrated with and without the absorbing screen, and smoke measurements were made at intervals of about five minutes during the tests.

The high concentrations of smoke occurred when cars were idling and as cars started at the beginning of tests or after stops. The minimum concentrations occurred during periods of good car operation.

APPENDIX E.—OPERATION OF HEATING PLANT. *H. P. Greenwald. Ibid., pp. 674–678.*

These tests were made with a view to studying the possibility of encountering extremes of temperature in the Holland tunnel. The author concludes:

The information obtained which may be applicable to the Hudson River vehicular tunnel may be summarized as follows:

(*a*) The tendency of the hot gases to go immediately into the upper duct and lose their heat therein.

(*b*) The fact that large temperature variations in the incoming air will be equalized by loss of heat to or absorption of heat from the walls.

(*c*) The large heat absorbing capacity of the walls.

(*d*) The fact that if the intake air is warm air of high humidity, deposition of water and possibly fogging will ensue on striking the cooler tunnel surfaces.

(*e*) These results convey the impression that it will be difficult to reach an excessive temperature in the Holland tunnel. Continued hot weather with no relief at night would be necessary to produce it. Furthermore, if the tunnel is washed down at regular intervals large quantities of heat will be removed from the walls directly by the water, and equal or greater quantities will be removed by the evaporation of the water remaining on the surface after the run-off.

APPENDIX F.—HEAT FLOW FROM TUNNEL AIR INTO CONCRETE WALLS. *G. R. Greenslade. Ibid., Oct., 1926, pp. 701–706.*

This investigation was undertaken to determine the amount of cooling that tun-

nel air undergoes by transfer of heat to the concrete walls, and to apply the data obtained to the conditions of the Hudson River vehicular tunnel.

. . . . .

The data show that unless the peak temperatures are maintained continuously for several days (8 or 10), the problem does not reduce to one approximating steady state conditions. This fact is very pertinent to the problem of removing excess heat from the air in the Holland tunnel, for it means that the cooling capacity of the walls, which has been accumulating during cool days, during the night, and at times of little traffic, is available to take care of peak temperatures lasting from a few hours to several days. In the ordinary case, the reduction in temperature affected by these conditions may amount to several or even many times the cooling due to the thermal conductivity alone.

APPENDIX G.—DISTRIBUTION OF CARBON MONOXIDE IN TUNNEL ATMOSPHERE. *S. H. Katz, J. J. Bloomfield, and L. J. Trostel. Ibid., pp. 706–718.*

Distribution of carbon monoxide throughout the experimental automobile tunnel was determined to ascertain the most desirable ventilation for the Holland tunnel. This appendix presents in detail the distribution of CO in the tunnel atmosphere under different methods of ventilation, and describes the essentials of the methods and apparatus used in determining it.

This section also details the apparatus and technic by means of which the four methods of transverse ventilation (Part III) were studied.

APPENDIX H. — PHYSIOLOGICAL DATA. *R. R. Sayers, H. R. O'Brien, F. V. Meriwether, and W. P. Yant. Ibid., Nov., 1926, pp. 757–766.*

The purpose of this section is as follows:

. . . . to observe and study any changes taking place in the bodies of men exposed during tests to tunnel gas atmospheres (as indicated by their body temperatures, pulse, sensations, and general behavior), and, above all, to determine accurately the concentration of CO in their blood following periods of such exposure; and to check the results obtained against the conditions of tests, but more especially against the concentration of CO in the tunnel atmosphere.

. . . . .

. . . . There would be a noticeable increase in the percentage saturation with CO of the blood under these conditions [*i.e.*, heat, humidity, and long exposure], but unless there is cause for a much longer period of exposure than normal, coupled with violent exercise such as cranking a car, etc., the added danger would be negligible, and could easily be covered by traffic regulations.

APPENDIX I.—USE OF THE SPECTROPHOTOMETER IN EXAMINING BLOOD. *H. R. O'Brien, W. P. Yant, and G. W. Jones. Ibid., Dec., 1926, pp. 817–825.*

A Hilger wave length spectrometer of the constant deviation type was used with a Nutting polarization photometer attachment.

Sufficient evidence has been obtained to give the authors of this appendix confidence in the spectrophotometric method. They have used it successfully in the recent investigation, and it affords good checks with other methods.

In this method the authors believe that they have a solution to the estimation of CO-Hb which is well suited to research problems, and results might be summarized as under:

1. It requires only a small quantity of blood, such as can be obtained by making a puncture wound, say 0.1 cubic centimeter.

2. No absolute measurement of blood is required. However, it is well to keep it as near the working concentration as can be conveniently done.

3. The actual time of analysis for each

sample in routine work is not more than 3 to 5 min.

4. Checks on analyses are afforded in the same sample.

5. Results can be secured regardless of prevailing conditions of daylight.

6. Accuracy is equal to that of any other method found and much better than most of them.

APPENDIX J. — PHYSIOLOGICAL TESTS UNDER CONTROLLED CONDITIONS. *R. R. Sayers, F. V. Meriwether, and W. P. Yant. Ibid., pp. 825–832.*

These experiments were performed and study made as follows:

1. The effect of long exposure to concentrations of 4 parts of CO in 10,000 parts of air.

2. The effect of strenuous exercise for periods of one hour in 4 parts of CO in 10,000 parts of air.

3. Controlled experiments on the effect of high humidity and temperature on the absorption of CO by the blood, and on additional physiological changes produced.

4. The effect of long exposure to concentrations of 2 and 3 parts, respectively, of CO in 10,000 parts of air.

The section is concluded as follows:

1. High temperature and humidity tends toward an increased saturation of the blood with CO, a marked rise in body temperature, pulse-rate, and respiration, and an earlier occurrence of symptoms.

2. Strenuous exercise causes an increase in the absorption of CO by the blood, and an earlier occurrence of symptoms.

3. Exposures of from 2 to 2½ hr. to 4 parts of CO in 10,000 of air will cause an accumulation of symptoms varying from decreased efficiency to basal headaches and nausea.

4. An exposure to 2 parts of CO in 10,000 gives mild symptoms at the end of 6 hr., and an exposure to 3 parts gives similar symptoms in from 2½ to 3 hr.

5. The effects of 4 parts of CO in 10,000 parts of air under various conditions may be summarized as follows, according to the experiments carried out by the authors of this appendix:

Condition	*Period, hours*	*Symptoms*
No exercise	1	No effect
No exercise	1½	Mild symptoms, no serious effect
Mild exercise	1	Mild symptoms, no serious effect
Strenuous exercise	½	Mild symptoms, no serious effect
No exercise in high temperature and humidity	1	Mild symptoms, no serious effect

These results are in concordance with the findings of others as given by Henderson, and emphasize the fact that the standard proposed for exposure of 45 min. of 4 parts in 10,000, or its equivalent in an average of concentrations from zero up to 6 parts in 10,000, assures an ample factor of safety.

Although some of these papers have already been published in the annual reports of the New York and New Jersey State Tunnel Commission and elsewhere, this series forms a valuable collection of important and original investigative work by the United States Bureau of Mines. Each of the papers contains pertinent tables, graphs, charts, and illustrations to which it is impossible to do justice in an abstract. The subject is of such widespread interest that it is hoped that means will be found to reprint the series in the form of a monograph. —*Philip Drinker.*

BOOK REVIEW

A Psychological Study of Individual Differences in Accident Rates. By *Eric Farmer*, M.A., and *E. G. Chambers*, M.A., Investigators to the Board. Industrial Fatigue Research Board, Report No. 38. Paper. Pp. 44. London: H. M. Stationery Office, 1926.

This is an interesting report which has just been published by the Industrial Fatigue Research Board and which opens up the possibility of a new method of approaching the study of accident causation. The report describes a research, the object of which was to see if there were among individuals any measurable psychologic differences corresponding in any degree to their accident proneness. Previous books that have dealt with the psychologic causes of accidents have been concerned with generalizations and have given instances of accidents which were due to nervousness, worry, or fatigue; this is the first attempt that has so far been made to go beyond such generalizations and to examine by scientific means the peculiarities of those who, while exposed to the same risk as others, yet sustain a larger number of accidents.

In two previous reports of the Board,[1] it was shown by statistical methods that people who were exposed to an equal degree of risk differed in their liability to sustain accidents. This does not mean that there is one class of persons who sustain accidents and another class of persons who do not, but that each individual differs from other individuals in his accident liability just as he differs from others in height, weight, and strength.

The research described in the present report is based on the previous work of Greenwood and Woods and of Newbold, it being taken for granted that people did differ in the way described, and an attempt was made to see if they differed in any other measurable way.

The method adopted was to give various tests to over 600 subjects separated into six different groups. The time of exposure to industrial accidents ranged from nine months to thirty-six months, and the age range was between 14 and 23 years. The tests given fell naturally into three groups. Group I consisted of certain sensorimotor tests which for reasons advanced in the report are called "aestheto-kinetic co-ordination" tests. These tests differed in the nature of the performances required of the subject, but they had a small element in common and their intercorrelation coefficient was about +.24. Group II consisted of certain tests connected with temperamental stability, and Group III consisted of tests involving the reasoning processes.

These tests were given to the subjects, and their performances in the tests were then compared with their

[1] The Incidence of Industrial Accidents upon Individuals with Special Reference to Multiple Accidents. M. Greenwood and H. M. Woods. Indust. Fatigue Res. Board, Rep. No. 4. London, H. M. Stationery Office, 1919.

A Contribution to the Study of the Human Factor in the Causation of Accidents. E. M. Newbold. *Ibid.*, Rep. No. 34. London, H. M. Stationery Office, 1926.

accident rates. This was done for each group separately, and when the final results were weighted according to the relation between performance and accident rate in the aesthetokinetic tests it was found that there was a difference of 48 per cent. in accident rate between those who passed the tests and those who failed. The tests connected with temperamental stability also yielded positive results, but those connected with the reasoning processes did not.

This report is confessedly of a preliminary nature; there are many aspects of the problem with which it deals that still have to be worked out before the results can be put to practical use. The chief value of the research lies in the fact that it has been shown that people who differ in accident liability do also differ in other measurable qualities. The particular qualities that have been measured may not be the most important factors making for a high accident rate, and the tests that have been used may not be the best ones for the purpose, but these preliminary experiments have yielded positive results, a fact which shows that the method employed is a profitable way of approaching the problem of the human factor in accident causation from a new angle.

These tests will have to be given to other groups to see if the results are repeated; other psychologic qualities will also have to be examined to see if they have any connection with accident liability; age norms for the tests yielding positive results will have to be established; and the question whether accident proneness is a general or a specific factor will also have to be determined, before accident incidence can be lessened by determining beforehand "the accident prone," those prone to accidents, and warning them from taking up dangerous occupations.

There is evidence in this research to show that those who tended to "report" sick most often, had more accidents, and were industrially less efficient than others. This, however, needs corroboration before it can be accepted with any confidence, but it is at least an indication that there exists a class of persons on whom modern industry makes an undue demand, so that they respond to their environment in an unfavorable way, causing loss and suffering both to themselves and to the community.

The tests employed, both those that yielded positive results and those that did not, are carefully described, diagrams of the apparatus used and details of its construction are given, and the statistical methods employed are explained. These details make it possible for other workers to examine critically the methods employed and the results obtained, and it is to be hoped that they will do so. If the full benefits are to be obtained from this line of research it is important that as many industrial occupations as possible should be examined, and the full details made public. By this means it should be possible as time goes on to collect a body of evidence of real value which may do much to mitigate one of the greatest sufferings caused by industry.